Institute of Space Sciences

Annual Report 2019

An institute of the Consejo Superior de Investigaciones Científicas (CSIC).
Affiliated with the Institut d'Estudis Espacials de Catalunya (IEEC).

Contents

Chapter 1

Introduction

1.1 History

The Institute of Space Sciences (from now on ICE) pertains to the 'Consejo Superior de Investigaciones Científicas' (the Spanish National Research Council, usually called CSIC). CSIC is the largest public institution dedicated to research in Spain and the third largest in Europe, and depends on the central government. CSIC has about 6% of all the staff dedicated to Research and Development in Spain, and they generate approximately 20% of all scientific production in the country. ICE is part of a new breed of research centers. It was officially created on January 17, 2008 (BOE #15, 3507, Orden ECI/4063/2007, of December 27, 2007), based on a proposal made about a decade before by the Governance of CSIC (Acta #11, 11/99). Thus, in 2018, the Institute would have been formally active for just 10 years.

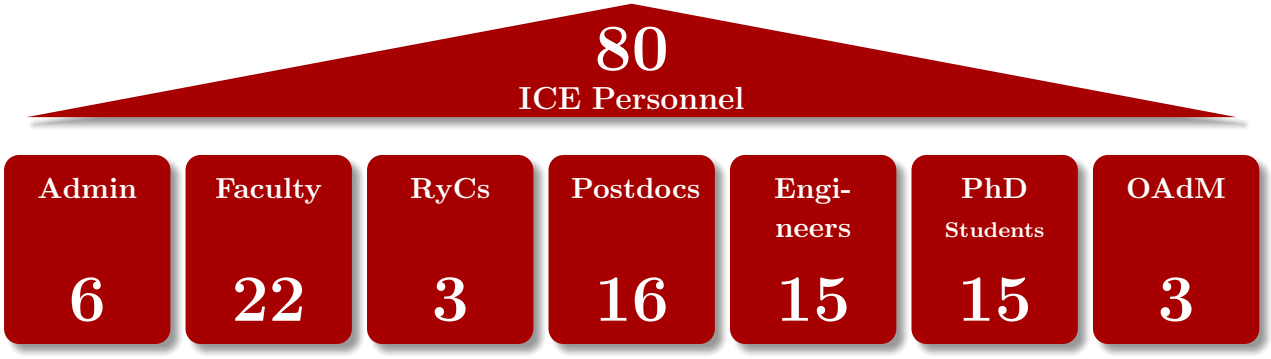
The Institute of Space Sciences articulates CSIC's participation in the confederation of independent institutes affiliated with the 'Institut d'Estudis Espacials de Catalunya' (IEEC). This is a non-for-profit foundation, founded in February 1996. Thus, ICE benefits from the interaction and collaboration with both the larger CSIC structure as well as with the Catalan community and government. The Director of the Institute of Space Sciences is at once, co-Director of the IEEC, while currently, one other member of ICE is executive Director of IEEC.

In 2015, ICE moved to a new facility located at the campus of the Universitat Autònoma de Barcelona. This building (property of CSIC and built on purpose for our Institute) has 3500 square meters of useful space, distributed in laboratories and offices.

In December 2019, there were 80 persons working full time at ICE. Of these, 22 were faculty members, 1 were staff engineers, 3 were senior Ramón y Cajal fellows (long-term, positions reminiscent to a tenure track), 16 were engineers and 15 were PhD students and other 15 were Postdoc. Six administration personnel gave support to operate the institute on a day-to-day basis. Constantly updated information on personnel numbers can be obtained from our website: `http://www.ice.csic.es/`

1.2 2019 in brief

Few defining data representing our activity at December 31st.



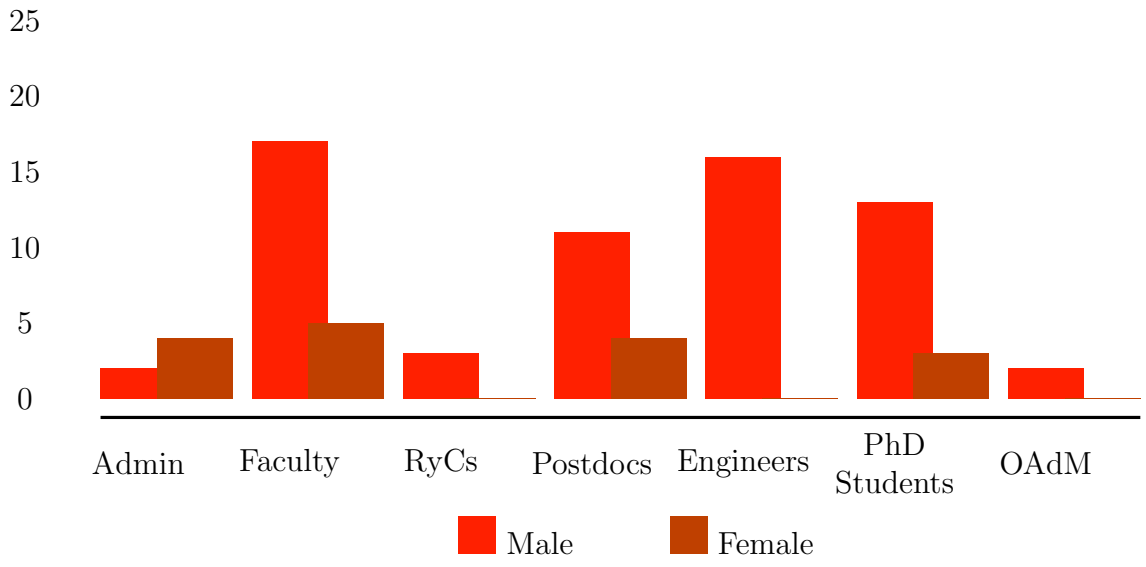


Table 1.1: Few defining data representing our activity at December 31st.

Indicator/Activity	Value
Personnel	
Persons in the institute	80
Faculty	22
Ramón y Cajal Fellows	3
Members obtaining new faculty positions in 2019	3
Visitors	
Short term visitors (< 2 weeks)	21
Long term visitors (> 2 weeks)	35
Publications	
Papers in international journals with peer review [a]	200
Papers published in proceedings	42
Citations (ADS information at December 31, 2019)	
Citations to papers in [a]	2.073
h-factor for papers in [a]	22
Citations (h-factor) to the 183 papers published in 2017	7871 (38)
Citations (h-factor) to the 166 papers published in 2014	8544 (51)
Projects	
New projects obtained in 2019	13
New competitive funding obtained via projects in 2019 (MEuros)	3.75
Awards	
National / International awards given to our personnel	3 / 6
Teaching and human resources	
PhD students in the Institute	15
PhD students graduating in 2019	4
MsS students in the Institute	7
MsS students graduating in 2019	7
Students in the Summer School of the Institute	42

Students in the Master on Astrophysics & Cosmology	23
Hours taught (# professors) by the Institute in the Master	212 (22)

Outreach

Scientific press releases	13
Outreach talks	12
Other outreach events	22

Seminars

Scientific talks at the Institute and Pizza Seminars	46
Scientific talks with speakers external to the Institute	10

Chapter 2

Institute Management

2.1 Individually named positions

- Director: Diego F. Torres
- Deputy Director: Ignasi Ribas
- Administrative Manager: Àngels Benet
- Head of the Astrophysics and Planetary Science Department (APS): Josep Miquel Girart
- Head of the the Cosmology and Fundamental Physics Department (CFP): Enrique Gaztañaga
- Head of the Advanced Engineering Unit (AEU): Serni Ribó

2.2 Formal bodies

- Director's Office: Director (chair) + Deputy Director + Manager
- Strategy Committee: Director (chair) + Deputy Director + Heads + Manager
- Junta (Institute Board): Director (chair) + Deputy Director + Heads + Manager (secretary) + 2 workforce representatives (J. M. Trigo- Rodriguez & C. Manuel)

2.3 Executive commissions and membership

- Computing: Pablo Fosalba (chair) + Martín Crocce + Josep Guerrero
- Workspace: Francisco Castander (chair) + Manager
- Outreach: Ricard Casas (chair) + Mar Mezcua + Gemma Busquet
- ICE Life: Nanda Rea (chair) + Carlos F. Sopuerta + Víctor Martín
- Teaching: Aldo Serenelli (chair) + Margarita Hernanz + Lluís Gesa

2.4 Advisory commission for institutional relationships: membership

- Director (chair) + Deputy Director + Margarita Hernanz + Jordi Isern + José M. Torrelles

2.5 International Advisory Committee

- Karsten Danzmann, Max Planck Institute for Gravitational Physics, Hannover. Expert on Gravitational Waves physics, is Director of the Division of Laser Interferometry and Gravitational Wave Astronomy.
- Manuel Martín-Neira, (ESA/ESTEC) Earth Observation, ESA Senior Staff Scientist. Expert on Earth observations, has been SMOS Principal Engineer, member of the Academie des Technologies of France.
- Luigi Stella, INAF - Osservatorio Astronomico di Roma, Italy, Full Professor Expert on high energy astrophysics. Editor of the Astrophysical Journal Letters. OMRI Commander (Italy) and Full Astronomer / Professor at INAF.
- Giuseppina Micela, Director, Osservatorio di Palermo. Expert on Planets and Exoplanets, clusters and star formation. Has been also a member of several steering committees in X-ray space missions.
- Michael F. Bode, Astrophysics Research Institute, John Moores University, Former Director. Expert on Novae and Supernovae and robotic observatories. Professor of Astrophysics. Has been leader in ASTRONET (the European Roadmap for Astronomy).

Chapter 3

Personnel

3.1 Administration

Bayona, Albert	Maintenance
Benet, Angels	Manager
Cortés, Noemí	Assistant to the Director
Guerrero, Josep	System Manager
Masip, Guadalupe	Accounting
Ruiz, Fina	HR and Travel

3.2 Faculty

Cardellach, Estel	Investigador Distinguido
Castander, Francisco Javier	Investigador Científico
Crocce, Martín	Investigador Distinguido
Elizalde, Emilio	Profesor de Investigación
Fosalba, Pablo	Científico Titular
Gaztañaga, Enrique	Profesor de Investigación
Girart, Josep Miquel	Científico Titular
Hernanz, Margarita	Profesor de Investigación
Isern, Jordi	Profesor de Investigación
Manuel, Cristina	Investigador Científico
Nofrarias, Miquel	Investigador Distinguido
Odintsov, Sergei D	Profesor de Investigación
Rea, Nanda	Científico Titular
Ribas, Ignasi	Investigador Científico
Ribó, Serni	Científico Titular
Rius, Antonio	Profesor de Investigación
Serenelli, Aldo	Científico Titular
Sopuerta, Carlos	Científico Titular
Tolos, Laura	Científico Titular
Torrelles, José María	Profesor de Investigación
Torres, Diego F.	Profesor de Investigación
Trigo-Rodriguez, Josep M.	Científico Titular

3.3 Staff Engineers/Technicians

Colomé, Josep

3.4 Ramon y Cajal Fellows

Amaro, Pau
Anglada, Guillem
Patruno, Alessandro

3.5 Postdocs and Postdoctoral Fellows

Borghese, Alice
Busquet, Gemma
Coti Zelati, Francesco
García, Alberto
Domínguez, Helena
Li, Weiqiang
Marín, Jonatan
Mezcua, Mar
Morales, Juan Carlos
Padullés, Ramón
Perger, Manuel
Pezzotta, Andrea
Pujol, Arnau
Khurshudyan, Martiros
Tutusaus, Isaac
Viganò, Daniele

3.6 Engineers/Technicians

Casas, Ricard
Galvez, José Luis
García, Emilio
García-Rigo, Alberto
Gesa, Lluis
Lamensans, Mikel
Martín, Victor
Mirabet, Eduard
Montón, Màrius
Nakhjiri, Nariman
Oliveras, Santi
Roma, David
Serrano, Santiago
Sierra, Carles

3.7 PhD Students

Añez, Nacho	FPI Fellow
Caixach, Mariona	FPI Fellow
Camacho, Benjamín	
Baroch, David	FI Fellow
Lafarga, Marina	FPI Fellow
Lin, Tingting	CSC Fellow
Lopez, Juan Pedro	FPI Fellow
Martín, Ivan	FPI Fellow
Mestre, Enrique	FPI Fellow
Viglione, Cristian Nery	FPI Fellow
Pocino, Andrea	FI Fellow
Renard, Pablo	
Ronchi, Michele	
Rosich, Albert	FPI Fellow
Tanbakouei, Safoura	

3.8 Montsec Observatory (OAdM) personnel residing at IEEC-CSIC

Herrero, Enrique
Moreno, David
Vilardell, Francesc

3.9 Percentage distribution by personnel category

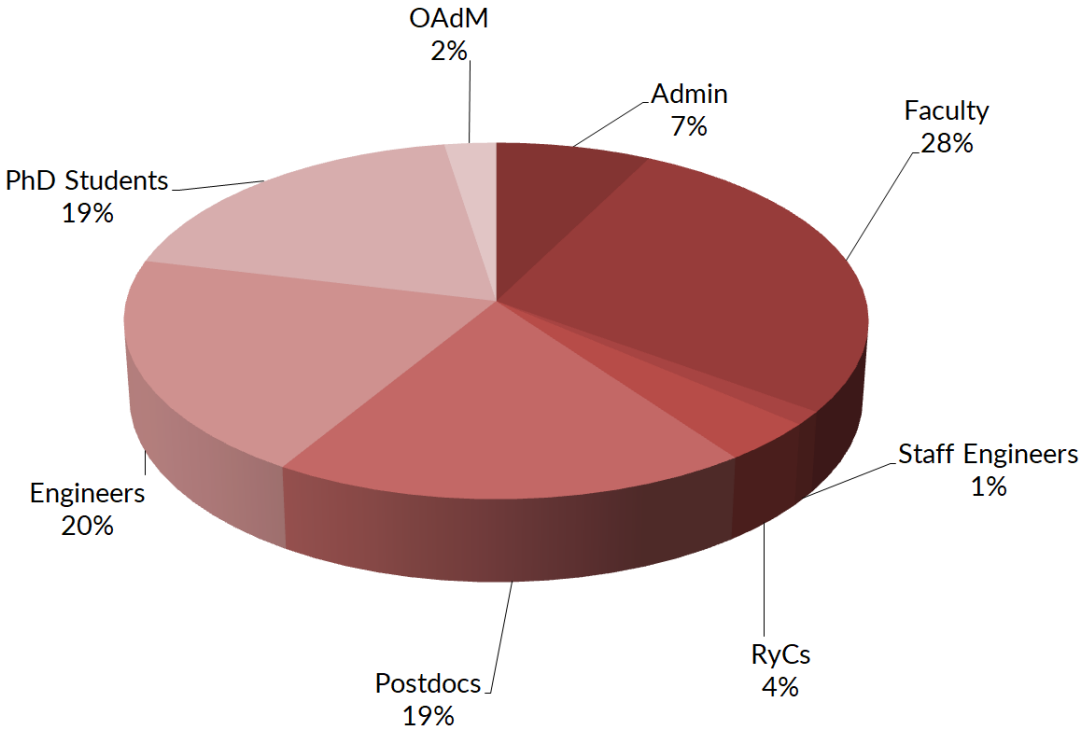


Figure 3.1: Distribution of the personnel of the Institute of Space Sciences.

3.10 Gender balance

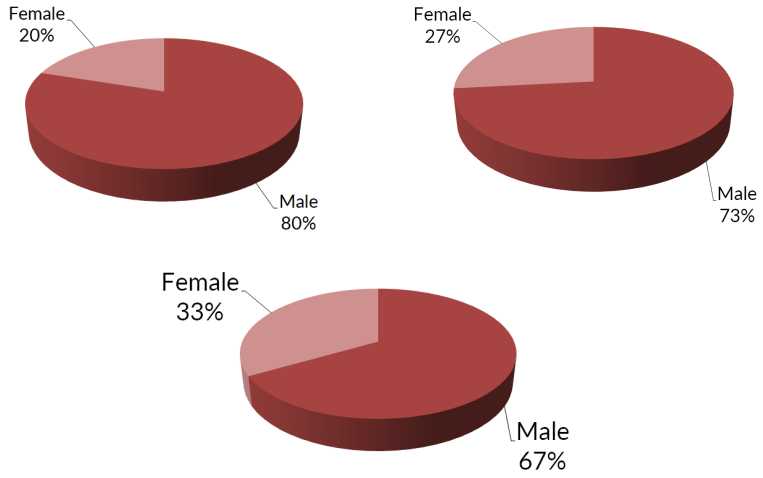


Figure 3.2: Gender imbalance of the faculty and Ramón y Cajal Fellows (left), postdocs (center), and PhD students (right) at the Institute of Space Sciences.

Chapter 4

Visitors

1. Alarcón, A., Arganne National Laboratory, 19/12/2019 - 17/01/2020
2. Allande, J., UAB-Convenio TFG, 31/10/2019 - 30/06/2020
3. Amadio, F., La Sapienza University, 11/06/2019 - 30/10/2019
4. Aoudia, S., Université de Bejaia, 09/10/2019 - 19/10/2019
5. Avila Gámez, D., UAB-Convenio grado, 30/09/2019 - 15/02/2020
6. Borghese, A., Anton Pannekoek Institute, 20/05/2019 - 20/07/2019
7. Camacho, B., UAB-Convenio doctorado, 01/10/2019 - 05/12/2019
8. Campos Llopart, F., UAB-Convenio grado, 01/06/2019 - 13/09/2019
9. Campos Llopart, F., UAB-Convenio Grado, 16/09/2019 - 20/02/2020
10. Canalda Sabaté, X., UAB-Convenio TFG, 01/11/2019 - 30/06/2020
11. Carballosa Calleja, A., UAB-Convenio prácticas de Máster, 01/02/2019 - 31/07/2019
12. Cardona Guillén, C., Instituto de Astrofísica de Canarias, 09/12/2019 - 13/12/2019
13. Carreño García, P., UAB-Convenio grado, 28/02/2019 - 30/06/2019
14. Cortes, P., NRAO, 21/10/2019 - 25/10/2019
15. Di Clemente, F., INFN, Gran Sasso, 18/11/2019 - 22/11/2019
16. Eggenmehier, A., Durham University, 12/11/2019 - 15/11/2019
17. Elias-Rosa, N., INAF-OAPd, 21/10/2019 - 30/04/2020
18. Fernández, I., UAB-Estudiante de Máster, 11/02/2019 - 31/05/2019
19. Fernández López, M., Instituto de Astronomía Teórica Experimental, 01/04/2019 - 30/06/2019

20. Gonzalez, E., Inst. de Astronomia Teórica y Experimental (IATE), 12/06/2019 - 12/08/2019
21. Graña, R., Inst. de Astronomia Teórica y Experimental (IATE), 01/05/2019 - 01/08/2019
22. Herrero-Illana, R., ESO, 01/12/2019 - 30/08/2020
23. Hidalgo López, D., UAB-Convenio grado, 01/07/2019 - 07/09/2019
24. Ho Zhang, J., UPC-Convenio Grado, 08/04/2019 - 31/07/2019
25. Hull, C., NAOJ, 21/10/2019 - 08/11/2019
26. Iñiguez Pascual, D., UAB-Convenio Grado, 07/11/2019 - 31/07/2020
27. Jiménez Torres, D., Universidad del Valle (Colombia), 14/03/2019 - 31/05/2019
28. Le Gouellec, V., ESO/ALMA& CEA/SACLAY, 21/10/2019 - 31/10/2019
29. Lillo-Box, J., Centro de Astrobiologia (CAB), 11/11/2019 - 14/11/2019
30. Mannarelli, M., INFN, Gran Sasso, 18/11/2019 - 21/11/2019
31. Mas i Sanz, E., UPC-Convenio Grado, 17/06/2019 - 13/09/2019
32. Miller, M., Universidad Nacional de La Plata, 04/03/2019 - 08/03/2019
33. Modroño Berdiñas, Z., Universidad de Chile, 10/12/2019 - 15/06/2020
34. Muñoz Pérez, C., UAB-Convenio grado, 04/03/2019 - 05/07/2019
35. Navarro, S., University of Texas (Austin), 01/10/2019 - 31/10/2019
36. Nuez Pladellorens, I., UAB-Convenio grado, 15/07/2019 - 15/09/2019
37. Oltean, M., UAB-Estudiante de Doctorado, 01/09/2019 - 31/10/2019
38. Paul, T., Indian Association for the Cultivation of Science, 03/10/2019 - 18/10/2019
39. Peña Asensio, E., UPC-Convenio Grado, 17/06/2019 - 31/01/2020
40. Porredon, A., , 01/03/2019 - 31/10/2019
41. Rapetti Serra, D., Nasa Ames Research Center, 19/12/2019 - 10/01/2020
42. Ribas Matas, C., UPC-Convenio Máster, 04/07/2019 - 15/09/2019
43. Rodríguez, A., Inst. de Astronomia Teórica y Experimental (IATE), 26/04/2019 - 22/07/2019
44. Rodriguez, F., Inst. de Astronomia Teórica y Experimental (IATE), 29/04/2019 - 26/07/2019
45. Rosich Salgado, A., Convenio Doctorado UB, 01/12/2019 - 30/09/2020

46. Rovira Ferrer, D., UPC-Convenio Grado, 08/07/2019 - 15/09/2019
47. Rubinstein, V., Observatorio de Córdoba (Argentina), 28/05/2019 - 04/06/2019
48. Samanta, G., Bits Pilani KK Birla Goa Campus, 23/05/2019 - 15/07/2019
49. Sanhuenza, P., NAOJ, 02/09/2019 - 14/09/2019
50. Silva Aguirre, V., Aarhus University, 04/07/2019 - 09/07/2019
51. Soldevila Casanovas, D., UAB-Convenio grado, 28/02/2019 - 30/06/2019
52. Torres Cuadrat, A., Institut Frederic Mistral, 01/10/2019 - 01/10/2020
53. Torres Rincón, J., Universidad de Frankfurt, 20/05/2019 - 24/05/2019
54. Untzaga, J., UAB-Convenio grado, 04/03/2019 - 28/06/2019
55. Vega Ferrero, J., University of Pennsylvania, 25/09/2019 - 31/12/2019
56. Wu, B., NAOJ, 02/09/2019 - 22/09/2019

Chapter 5

Missions and experiments

Here, we provide a brief description of the focus of our research related to missions and experiments, together with recent news.

5.1 ...of the Department of Astrophysics and Planetary Sciences

- **ARIEL:**

  Aim of our participation: The ARIEL mission concept is developed by a consortium of more than 70 institutes from 17 countries. IEEC-CSIC is one of the co-PI institutes (co-PI: Ribas) and leads the Spanish contribution (PI: Ribas; National Project Manager: Colomé), which also includes the Instituto de Astrofísica de Canarias and the Universidad Politécnica de Madrid. The groups at CSIC and UB, coordinated through IEEC, participate in various aspects of the mission. We are responsible for the design, implementation, assembly and verification of the Telescope Control Unit (TCU). The TCU performs the thermal monitoring and control of the telescope and payload module; drives the On-Board Calibration Source (OBCS); and controls the M2 refocusing mechanism (M2M) under operation from the ground. The TCU has become a stand-alone unit, under the responsibility of the Spanish consortium. Presently is a sub-system of the telescope assembly, jointly with the M2M. It will also implement command handling, data formatting and the communication to the spacecraft. This project benefits from the expertise gained in previous missions (Solar Orbiter and LISA Pathfinder) for the development of flight electronics and software to contribute to the consolidation of the requirements and the evolution of the design. We are also responsible for the design and manufacture of the mechanisms of the secondary mirror (M2M) refocusing system. The M2 re-focusing system is necessary to ensure that the telescope is in best focus and meets wave-front error requirements when in operations and it is located on the M2 mirror. This telescope component is very close, both at logical and physical levels, to the warm electronics and software of the TCU and, therefore, lending our group responsibility on a critical part of the ARIEL payload, from the electro-mechanics to the software logics. Furthermore, we lead the mission planning task by using our expertise on scheduling techniques to optimize operations and studies the impact

of mission design requirements. This is a key building block of the Science Operations Assumptions Document (SOAD) and is the basis to define the Science Ground Segment of the mission.

Recent Developments: The activity during 2019 has been focused on developing Phase B1 of the mission, which will culminate in 2020 with the Mission Adoption Review (MAR) and the subsequent adoption of the mission by the ESA Space Program Committee. The main technological tasks during 2019 were focused on the study and design of the engineering solutions that the mission will have to implement. A first bread-board was designed to check the initial approach to the thermal measurement, including some novel solutions based on a current source. Furthermore, a first version of the tungsten filament control has been designed as a bread-board. The system has been characterized, and it is awaiting tests with the tungsten filament. Also, a circuit to drive the LEDs is under design. The M2M development activity was initiated in 2019 under the ESA Core Technology Program (CTP). The activity includes all the phases required to consolidate the M2M requirements and to bring M2M to TRL6 by the time of MAR. In particular, the activity is testing the capability of the M2M actuators to operate at the ARIEL required temperatures. A preliminary M2M assembly design was provided during 2019, foreseeing a titanium structure with aluminum interfaces.

With regards to mission planning, we are designing a scheduling software tool based on Artificial Intelligence to calculate the mission plan. In particular, we have considered Multi-Objective Evolutionary Algorithms that efficiently explore the large parameter space of this problem in look for the optimal solution fulfilling several objectives at the same time. During 2019, we have worked on upgrading the code to consider the ARIEL mission constraints. Besides, we made use of the scheduling tool to assess the feasibility of the mission, demonstrating that it is possible to achieve the science goals in terms of the number of planets surveyed while optimizing the time usage

On the science side, we are leading the Stellar Activity WP, as well as participating in the Ephemeris WP. The main scientific tasks during 2019 have focused on studying the effects of stellar activity on transit spectroscopy, due to the spectrophotometric variability caused by starspots, and on collaborating in the selection of the target sample. Most of our attention has been on analyzing the potential benefits of having contemporaneous multi-band photometry together with the ARIEL observations to better characterize stellar variability and thus be able to correct out the effects on the acquired spectra. As a test case, we analyzed +/-600 days of multi-band photometry from the TJO and STELLA telescopes of the exoplanet host star WASP-52. We model the observations with our own StarSim tool to perform the inversion of the light curves. We are able to reconstruct a probability map of active longitudes and the relevant stellar active region parameters. For WASP-52 b, which has peak-to-peak photometric variations of +/-7% in the visible, we find that the residual effects of unocculted dark spots on the measured transit depth after applying the correction resulting from our model are about 40 ppm at 550 nm and 10 ppm at 6 um. Our methodology applied to such active star demonstrates a mitigation of the activity signal by a factor of 20-30 from the visible to the near infrared, which

should allow ARIEL to fulfill its science goals. The upgraded StarSim algorithm and its application to WASP-52 and the ARIEL mission will be published in an upcoming paper (Rosich et al. 2020, subm.).

- **CARMENES:**

  Aim of our participation: IEEC-CSIC has a prominent role in CARMENES. We are responsible for science preparation and exploitation through the figure of the Project Scientist. In this capacity, the Institute of Space Sciences led the selection of the stars that is being searched for planets, the collection of all necessary information to guarantee the best precision and the analysis of the data acquired to uncover habitable planets.

  Besides the scientific role, the Institute of Space Sciences is also responsible for key technology packages of the CARMENES spectrograph, which are the Instrument Control System (ICS) and the scheduling system. The ICS is the "brain" of CARMENES and centralizes all the subsystems to control the proper working of the instrument, its performance, and environment variables. The ICS communicates and collects data from a variety of sources using the modern and versatile Internet Communications Engine architecture that ensures a robust operation. The scheduler is a complex piece of software factoring in a large number of variables (target properties, prioritization, environment variables) to find the optimum target to observe at each point in time. Proper scheduling is essential to maximize the science output of CARMENES as it optimizes its efficiency.

  Recent Developments: Four years after the start of the survey, CARMENES results are spectacular. Regarding planet discoveries, the consortium has published 18 new planets and the publications of an additional 8 planets are currently in preparation. The newly-found planets are especially valuable since they populate a region of the parameter space that until now had not been sampled in detail. Moreover, 9 of the discoveries correspond to planets orbiting stars with masses less than 0.2 M. Before, only 7 planets with dynamical mass determinations were known, which means that CARMENES has more than doubled the number in this mass range. Among the "fauna" of planets discovered by CARMENES there are planets of Neptune mass in temperate orbits, planets in close but eccentric orbits, planets in binary star systems, planets around active stars, or the second-closest planet with transits, to name a few. The full list can be found here.

  There are three discoveries that deserve special attention. The first big announcement was the discovery of a cool super-Earth with a mass about 4 M and an orbital period of 233 days around Barnard's Star (Ribas et al. 2018, Nature, 563, 365), the second closest star system to us. This elusive planet was detected thanks to the combination of hundreds of radial velocity (RV) measurements obtained over two decades and using various instruments, among which CARMENES played a key role. In mid-2019, the discovery of a planetary system with at least two planets around the ultra-cool Teegarden's Star (Zechmeister et al. 2019, A&A, 627, A49) was published. CARMENES demonstrated a unique ability to take precise Doppler spectrometry for stars of such low mass. With velocity amplitudes below 2 m s-1, the two planets have minimum masses almost identical to that of the Earth and are

located in the HZ around their star. This discovery illustrates the success of the core science case of CARMENES, as the system found was the prime objective of our searches. And finally, in September 2019 the discovery of GJ 3512 b, a giant planet orbiting a star with a mass ten times lower than the Sun, was made public (Morales et al. 2019, Science, 365, 1441). Explaining its existence is a challenge for the most advanced models of planetary formation by core accretion and forces us to resort to more "exotic" models, such as formation by gravitational instability of the protoplanetary disk.

Besides the exoplanet discoveries within the main survey, the CARMENES instrument has also been extremely successful in studying known transiting planet atmospheres. In addition to detecting the presence of various molecules (notably water vapor), CARMENES, thanks to its unique near-infrared channel, has pioneered the observation and measurement of the He I 1083 nm feature (Nortmann et al. 2018, Science, 362, 1388), which has opened the door to accurately probing atmosphere evaporation processes from the ground.

- **CHEOPS:**

  Aim of our participation: IEEC-CSIC is involved in the scientific aspects of the CHEOPS mission through its participation in the Mission Board and Core Science Team. In addition, during 2019 we reached an agreement with the mission control team to provide them with our schedule visualization tool. This will be useful to the project by allowing mission planners to visually evaluate the plans produced by the scheduling algorithm, and detect possible alternatives for optimization.

  Recent Developments: Early in 2019, the CHEOPS mission (spacecraft and payload) was fully integrated in the premises of Airbus Defence& Space in Madrid. A successful final review preceded its shipment to the launch site, which occurred in October. The mission was successfully launched on 18 December 2019 with a Soyuz-Fregat rocket from the European Kourou spaceport. Because of its modest size and weight, it was a secondary passenger. Since launch, all systems checks have been successful and the telescope cover was opened on 29 January 2020, leading to the acquisition of the first images. So far, the telescope and instrument are in perfect health and the start of routine science operations is expected to occur in March 2020.

  In parallel, the Science Team has worked on fine-tuning the science case and on defining the transiting planet sample that CHEOPS will observe. In this latter aspect, the synergy with the TESS mission from NASA, which was launched in April 2018, is evident (TESS is discovering hundreds of planet candidates that CHEOPS can observe). To exploit this, the IEEC-CSIC team has been leading the joint TESS-CHEOPS team (and the corresponding CHESS project) and has explored and established the benefits of the collaboration.

- **CTA:**

  Aim of our participation: The Institute has been involved in the CTA Project from 2006 in both the technical, as part of the then called Array Control and DAQ System (ACTL) working group and leading the scheduler team, and in preparing

the scientific exploitation of the observatory. Concerning the scientific exploitation, our institute is leading a number of the 'Key Science Programs', putting an effort of maximising the physic output of the observatory. Our team is responsible for designing the Galactic observations of CTA. We are also in charge of coordinating the studies for the first light Galactic observations of CTA and its pathfinders, and of coordinating the necessary multi-wavelength activities (such MoU with other large installations). This follows our earlier efforts: we have been the global Science Coordinator of the whole collaboration for 8 years in the period 2007-2014, having responsibilities in the scientific definition of the experiment, up to Technical Design Report.

Recent Developments: The CTA northern hemisphere array site in La Palma is now in full-fledge development. In its first attempt to detect a gamma-ray source, the Large Size Telescope prototype (LST-1) successfully detected its first gamma-ray signal on 23 November 2019 when it pointed to the Crab Nebula. Our group continues to work on preparing the telecope control, the CTA scheduler, and deepening into a possible implementation of a muti-facility scheduling concept.

- **eASTROGAM:** e-ASTROGAM (enhanced ASTROGAM) is a mission proposal to ESA M5 (medium-size) call, with a detector composed by a Silicon tracker, a calorimeter, and an anticoincidence system, dedicated to the study of the non-thermal Universe in the photon energy range from 0.3 MeV to 3 GeV. The proposal was not accepted by ESA for feasibility study. A reduced version – All Sky Astrogam - has been proposed in response to the call for fast missions by ESA (October 2018).

  Aim of our participation: We were co-responsible of the Si-tracker part of the payload (double sided Si strip detectors), in collaboration with the IMB-CNM (CSIC) institute. Si-strip detectors d are similar to the CdTe detectors being developed and tested in the Radiation Laboratory of our institute.

  Recent Developments: White paper collecting all the science topics that eASTROGAM could address. We were conveners of the "Explosive nucleosynthesis and chemical evolution of the Galaxy" topic (J. Isern) and Thermonuclear Supernovae and Nova explosions subtopics (J. Isern, M. Hernanz). Publication in the JHEAP (2018). Participation in the presentations of eASTROGAM in the SPIE conference 2018 in Austin (Texas, USA), and in the corresponding paper.

- **eXTP:**

  Aim of our participation: The enhanced X-ray Timing and Polarimetry mission (eXTP) is a China-led science mission designed to study the state of matter under extreme conditions of density, gravity and magnetism. Primary goals are the determination of the equation of state of matter at supra-nuclear density, the measurement of QED effects in highly magnetized stars, and the study of accretion in the strong-field regime of gravity. Primary targets include isolated and binary neutron stars, strong magnetic field systems like magnetars, and stellar-mass and supermassive black holes. The eXTP satellite is envisioned to be launched in 2027, with four instruments onboard, two of them (LAD and WFM) led by Europe. The WFM is led by ICE (PI: M. Hernanz). ICE will supply the collimator, detector

support plate and coded mask of each camera, plus the mechanical and thermal configuration of the whole WFM, and be responsible of the Assembly, Integration, Verification and Test of the six WFM cameras.

Recent Developments: LAD and WFM instruments have successfully passed an advanced phase A review carried out by ESA in August 2019. The WFM team is working in close collaboration with the eXTP satellite Prime and IHEP (both in China) in order to define interfaces (mechanical, thermal and electrical) at system level. Teleconferences and meetings are taking place to discuss about this important issue. We attended a meeting with the Prime in Shanghai (China) last October. Now, we are in phase B1 and addressing the design of each subsystem taking into consideration that all components, materials and processes must be US-free. This fact is quite challenging and requires an extra effort since alternative to off-the-shelf components should be identified and they should be space qualified.

- Participation in the "eXTP Interface" meeting with eXTP satellite Prime in Shanghai, 14-16 October 2019.
- Organization of the RIA-meeting "Science and development of eXTP in Spain" at ICE in Barcelona, 21-22 January, 2020. http://riastronomia.es/en/science-and-development-of-extp-in-spain-2/.
- Participation in the project, "Characterization of atomic oxygen erosion resistance of X-ray filters and thermal foils for the new X-ray astronomy era" in order to use ESA's Atomic Oxygen Erosion Effects (ATOX) Facility. Our project has been accepted by ESA In short, we will begin the test campaign in ESA's atomic oxygen simulator and will allow us to investigate its erosion effects on temperature-controlled external single layer insulator (SLI) samples in vacuum.

- **Fermi:**

Aim of our participation: The Fermi Gamma-ray Space Telescope was launched from the Kennedy Space Center on June 11, 2008. The verification phase was completed on August 11, 2008, and Fermi is now in nominal science operations. Since then, the Fermi-LAT collaboration has published several hundred papers on the high energy phenomenology of the transient and steady sky.

Fermi has two gamma-ray instruments: the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). The LAT is a wide-field gamma-ray telescope (covering from 30 MeV to 300 GeV). From the start of regular observations, LAT scans the sky, providing all-sky coverage every two orbits, and accumulating integration time in all directions. LAT observations may also be interrupted by target of opportunity observations, follow up of GRB, or pointed observations. The GBM is an all-sky monitor (10 keV - 25 MeV) that detects transient events such as occultations and gamma-ray bursts.

The PI is P. Michelson (SLAC & Stanford), earlier leading a constructing consortium of 5 nations and currently a scientific consortium of 13 (including Spain). Our institute is the only institute in Spain with full members in the Fermi-LAT collaboration

(since 2007, before launch). We are devoted to the study of the high-energy Galactic sky, focusing on binaries and the pulsar/pulsar-wind nebula/supernova remnant complex.

As members of the collaboration we have participated in the day-to-day running of the experiment, and conducted a variety of tasks such as being Internal referees for papers, participating in Committees / meetings / thinkshops / collaboration meetings / etc. and helped in preparations for several NASA Senior Science Reviews

We have also had the following technical involvement

- Definition of mock population for data challenges
- Development of algorithms for source class identification
- Acted as Flare advocates & daily running checks (similar to an observational shift, a couple per year)
- Participated on the On-orbit calibration & development of responses
- Validation of the time-difference analysis technique for radio-quiet pulsars

Highlights of our the Institute's contribution to the mission include leading the collaboration work when publishing Fermi's first paper on SNR observations, or the first ever detection of orbital GeV variability, or the first search for magnetar emission in gamma-rays, or the first detection of starburst galaxies, among many others.

- **PAZ:**

  Aim of our participation: The "polarimetric radio occultations" (PRO) measurement concept was conceived at the Institute to measure atmospheric heavy precipitation in addition to the standard radio occultation thermodynamic products. Proof-of-concept experiment designed and managed at the Institute: "Radio Occultation and Heavy Precipitation aboard PAZ" (ROHP-PAZ). It involves agreements with NOAA, UCAR, JPL and Hisdesat. Only spaceborne technology to provide vertical profiles of both thermodynamic variables and precipitation, with potential to contribute to improving modeling/forecast/climate projections of these extreme events.

  Recent Developments: During 2019, the ROHP-PAZ Team has successfully conducted an in-orbit calibration of the PRO antenna. Tests of near-real time (NRT) dissemination of the thermodynamic products to some weather services proved that these data sets can be operationally assimilated into numerical weather prediction (NWP) models, with some reduction of the forecast error (US Navy Global Environmental Model, NAVGEM). ROHP-PAZ thermodynamic products are now being disseminated to weather services worldwide through the World Meteorological Organization Global Telecommunication System since December 2019.

- **PLATO:**

Aim of our participation: The IEEC-CSIC is leading a workpackage that has as its main task to distribute and optimize the observations of the ground-based follow-up using the proven expertise in sophisticated scheduling algorithms. The exoplanet candidates received from the PLATO Data Center will be distributed among the different facilities according to the relevant parameters and to the availability of observing time.

Recent Developments: PLATO was adopted by ESA as its M3 mission in June 2017 and from then on it entered the Implementation phase. On our side, we have been progressing on the design on the scheduling suite, for which specific requirements are being discussed as a result of the PLATO Input Catalog meeting in Padova in September 2019. One of the main open points under assessment is the interfacing between the scheduling tool and the various facilities that will be registered in the PLATO follow-up consortium. Various solutions are being tested, most importantly those based on the Virtual Observatory standard. During 2019, the first generation of the grid of stellar models has been produced. This is now in the process of being implemented in the first prototype of the stellar parameters pipeline being designed by the PLATO Science Management, and to be implemented by the PLATO Data Center as part of the PLATO official data pipeline.

- **Strobe-X:**

Aim of our participation: The Spectroscopic Time-Resolving Observatory for Broadband X-rays (STROBE-X) https://gammaray.nsstc.nasa.gov/Strobe-X/ probes strong gravity for stellar mass to supermassive black holes and ultradense matter with unprecedented effective area, high time-resolution, and good spectral resolution, while providing a powerful time-domain X-ray observatory. STROBE-X was approved by NASA as a Probe-class Mission for the 2020 US decadal survey; its feasibility study, where ICE participates, was performed in 2017-2019. STROBE-X includes a WFM inherited from LOFT ESA M3 pre-selected mission.

Recent Developments: During 2019 the STROBE-X final study report has been presented to NASA. We have contributed to the general science and the specific sections about the WFM instrument, for which we are co-PIs (M. Hernanz). This has been presented to the US Decadal Survey:

  - "STROBE-X: X-ray Timing and Spectroscopy on Dynamical Timescales from Microseconds to Years", P. S. Ray et al. including M. Hernanz, Bulletin of the AAS 51, Issue 7, id. 231 (2019) - Astro2020: Decadal Survey on Astronomy and Astrophysics, APC white papers.
  - "STROBE-X: X-ray Timing and Spectroscopy on Dynamical Timescales from Microseconds to Years", Wilson-Hodge, C. A., Ray, P. S., et al. including M. Hernanz, presentation to the HEAD (High Energy Division) Meeting of the AAS (American Astronomical Society), Monterrey, CA (USA), March 2019.
  - Response to a NASA RFI about STROBE-X study, December 2019

5.2 ...of the Department of Cosmology and Fundamental Physics

- **DES:**

  Aim of our participation: DES will map 300 mill galaxies over 1/8 of sky (5000 deg2) to z 1.3 in 5 broad band bands (grizY) to measure the dark energy equation of state using a combination of methods: weak lensing, cluster abundances, baryon acoustic oscillations and supernovae. Together with IFAE and CIEMAT we are responsible for building and maintaining the electronics and guiding of DECam in the 4m Blanco Telescope in Chile.

  Recent Developments: In 2019, DES has finished observations (6yr in total) to the nominal 10 exposures in 5 bands (grizY) over 5000 square degrees of the sky. Over 230 scientific papers on main journals have been published so far. Finished the Y1 cosmological results and data released. During 2019 we have progress on Y3 results (over the full footprint). First supernovae and dark energy measurements published. Legacy science include: Gravitational Wave follow-up, Milky way satellites and planets. Our institute is leading the clustering and redshift working groups.

- **DESI:**

  Aim of our participation: The Dark Energy Spectroscopic Instrument (DESI) collaboration is building a large field of view multi-fiber spectrograph to perform a spectroscopic survey of tens of millions of galaxies to study dark energy using baryon acoustic oscillations and redshift space distortions. The Institute of Space Sciences, together with IFAE, has built the guider and focusing (GFAs) units of the instrument. We have developed the guiding software. We also lead the Image Validation Working Groups and participate in the collaboration management in the institutional board.

  Recent Developments: In 2019, our group (IFAE, ICE) delivered the remaining and last GFA units for the DESI focal plane that were installed in the focal plane. The instrument saw first light in October 2019 and then started commissioning. We have been involved in the commissioning of the guiding system.

- **Euclid:**

  Aim of our participation: Euclid is the European Space Agency cosmology mission to study the accelerated expansion of the universe also known as dark energy. The Institute of Space Sciences has leadership roles and visibility in the mission: we belong to the ESA Euclid Science Team and we currently hold the Chair position of the Euclid Consortium Board, we lead the simulation effort and contribute to hardware and software.

  Recent Developments: In 2019, the NISP (NearInfrared SpectroPhotometer) instrument started integration, assembly and testing of all its sub-systems including the Filter Wheel Assembly (FWA) that our group (IFAE, ICE) delivered. We have been improving the Flagship galaxy mocks that the Euclid Collaboration have been

using. The Flagship simulation is the largest N-body cosmological simulation to date. We (PIC, ICE) have produced the last release of the Scientific Challenges 4,5,6 (SC456) of the Science Ground Segment. The SC456 was used for the Technical Key Point 2 Review that was successfully passed in November 2019.

- **LISA and LISA Pathfinder:**

  Aim of our participation: After the inauguration of Gravitational Wave Astronomy, with the first detection by the US LIGO observatory and the 2017 Nobel Prize in Physics, the Laser Interferometer Space Antenna (LISA, the ESA-L3 mission) will open a new window of the Gravitational-Wave spectrum: The low-frequency band. LISA is an all-sky monitor that will offer a wide view of a dynamic cosmos using Gravitational Waves, providing the closest ever view of the infant Universe at TeV energy scales; LISA has known sources in the form of verification binaries in the Milky Way (ultracompact binaries), and can probe the entire Universe, from its smallest scales near the horizons of black holes, all the way to cosmological scales. From these measurements we expect revolutionary discoveries in Astrophysics, Cosmology and Fundamental Physics. The LISA Pathfinder mission of ESA, launched on December 3rd, 2015 and operating March 1st, 2016 through June 30th, 2017, successfully demonstrated the main technology for LISA, in particular the fundamental concept of gravitational wave sensing in flight. The Gravitational Astronomy Group of the Institute of Space Sciences (ICE) leads the Spanish contribution to the LISA mission and has led the Spanish contribution to the precursor technology demonstration mission, LISA Pathfinder. Carlos F. Sopuerta (ICE) is currently a member of the LISA Consortium Board, which organizes the member states' contributions to the LISA payload and a member of the "LISA Science Study Team" (SST) of ESA. Miquel Nofrarias (ICE) is the Data and Diagnostics Lead from the LISA Instrument Group (LIG), representing the Spanish contribution to the mission and also a member of ESA's LISA System Engineering Office (SEO). Josep Colomé (ICE) acts as the Spanish LISA National Project Manager. In parallel, members of the Gravitational Astronomy Group - LISA participate in different working groups of the LISA Consortium such as the "LISA Data Processing Group" (LDPG). The group contribution to LISA, following the successful experience of the LISA Pathfinder mission, is the Data and Diagnostics Subsystem. The Data subsystem consists of the mission payload computer along with all the corresponding software (both operating system and applications software). The Diagnostics subsystem consists of a series of sensors and actuators of high precision and unprecedented stability, together with all the associated electronics, that will provide essential information about the environment of the LISA measurement system. Diagnostics are: Thermal (sensors and thermal actuators), Magnetic (magnetometers, coils and electromagnetic antenna), Radiation (radiation monitor).

  Recent Developments:We are currently working on the developments for the Phase A of LISA, and have recently passed the Mission Consolidation Review (MCR). Thanks to the expertise and lead acquired with LISA Pathfinder, the Gravitational Astronomy Group is currently leading the ESA contract 'LISA Enhanced Temperature Subsystem' (LETS) which plans to develop a first prototype (TRL4) of the future LISA temperature subsystem. This includes technological improvements

in the read-out and a ultra-stable test bench to be installed at ICE premises. M. Nofrarias (ICE) is leading this international effort together with the German Space Agency (DLR) and SENER Aerospacial.

- **PAU:**

  Aim of our participation: PAUcam is a unique instrument design to make high accuracy photometric surveys using 40 narrow band filters spaced by 100A in range 4500-8500A. Together with IFAE we are responsible for building and maintaining of the PAUcam in the 4m WHT Telescope in La Palma. Our institute is leading the Science and operation of the PAU Survey. We also manage the international collaboration and data reduction.

  Recent Developments: In 2019, University of Portsmouth joined PAUS with 20,000euros funding. During 2019 we completed over 200 nights of Observing covering over 50 deg2 Survey area . We have also started a DEEP COSMOS pilot project to extend the Survey one magnitude fainter (I¡24). We have published some additional papers on data analysis and perform the first clustering and intrinsic alignment measurements. We continue improving the data reduction and operation of the Survey and are using the PAUS data to calibrate photo-z in DES.

Chapter 6

Seminar List

6.1 Talks at ICE

1. Stefano Anselmi , What do we want from Baryon Acoustic Oscillations?, 21/02/2019
2. M. Bordag, Free energy for Dirac comb, 12/03/2019
3. Dr. Gauranga Samanta, Bouncing solutions in modified gravity, 01/07/2019
4. Dr. Misao Sasaki, PBHs-as-CDM scenario and Gravitational Waves, 08/07/2019
5. Prof. Rory Barnes, After the Habitable Zone, 30/07/2019
6. Andreu Font Ribera, Studying the Expansion of the Universe with quasar spectra, 13/09/2019
7. Tanmoy Paul, Inflationary universe in F(R) gravity with antisymmetric tensor fields and their suppression during its evolution, 07/10/2019
8. Branko Dragovich, Dark Matter and Dark Energy from a New Nonlocal Modified Gravity, 07/10/2019

6.2 Pizza-Lunch Seminars

1. Porredon, A. M., Multi-probe Cosmological Analysis with the Dark Energy Survey, 18/01/2019
2. Mezcua, M., Feeding and feedback from little monsters: black holes in dwarf galaxies, 25/01/2019
3. Gaztañaga, E., The cosmological constant and the size of our Universe, 01/02/2019
4. Tutusaus, I., Cosmic acceleration and type Ia supernovae luminosity-redshift dependence, 08/02/2019
5. Dimitris Stamatellos, Too fast, too furious: rapid planet formation by gravitational instability, 15/02/2019

6. Paul Beck, Asteroseismology of Red-Giant and Solar-Analogue stars in the golden age of space photometry and ground-based spectroscopy, 22/02/2019
7. Elizalde, E., On the history of the Universe expansion: Edwin Hubble, Georges Lemaitre and Vesto Slipher, 01/03/2019
8. Marcelo Miller Bertolami, Pulsations in (few, exotic) hot subdwarf stars, 08/03/2019
9. Albert Rimola, Chemical Complexity in Space and Earth Induced by Solid State Surfaces. Investigations by means of Quantum Chemistry, 15/03/2019
10. Añez, N., Does the size matter?: The case of HH80-81 disk, 22/03/2019
11. Alberto Rebassa Mansergas, White dwarfs in the Gaia era, 05/04/2019
12. Tolos, L., EoS in neutron stars - recent results on cooling and tidal deformabilities, 12/04/2019
13. Trigo-Rodriguez, J. M., The discovery of a comet fragment inside a meteorite provides clues about water delivery, 26/04/2019
14. Manuel Fernández-López, Outflows from young stars, 03/05/2019
15. Màrius Oltean General relativity and extreme-mass-ratio binaries, 10/05/2019
16. Adriana R. Rodriguez Kamenetzky, Particle acceleration in protostellar jets: an observational approach, 17/05/2019
17. Diego Torres, The heart of darkness, 24/05/2019
18. Victoria Rubinstein, Public communication of science. A portal to the public: IATE &OAC experience, 31/05/2019
19. LIN, T., Simulations on reverberating and superefficient pulsar wind nebulae, 07/06/2019
20. Isern, J., The star formation history in the solar neighborhood as told by massive white dwarfs, 14/06/2019
21. Serrano, S., Simulating Pixels, 21/06/2019
22. Amaro-Seoane, P., X-MRIs and IMRIs - From extremely large to intermediate, 28/06/2019
23. Luigi Foschini , THE 1908 TUNGUSKA EVENT: 111 YEARS AFTER, IT STILL MAKES YOU THINK, 12/07/2019
24. Torrelles, J. M., Rapidly Evolving Episodic Outflow in the Fastest Water Fountain, 04/10/2019
25. Domínguez Sánchez, H., Stellar Population of galaxies and their evolution, 11/10/2019
26. Tutusaus, I., Tension on the Hubble constant: systematic uncertainties or new physics?, 18/10/2019

27. Morales, J. C., Recent results from CARMENES , 25/10/2019
28. Chat Hull, Star formation, polarization, and magnetic fields in the ALMA era, 08/11/2019
29. Serni Ribó, Apadrina un carolingi, 15/11/2019
30. López-Zaragoza, J. P., Magnetic environment and experiments on-board LISA Pathfinder, 22/11/2019
31. Mark Gieles, Black hole in globular clusters, 29/11/2019
32. Sopuerta, C., ELGAR: The European Laboratory for Gravitation and Atom-interferometric Research, 13/12/2019

6.3 Colloquiums

1. 1 Prof. Dr. Luciano Rezzolla, The first image of a black hole, 25/09/2019

6.4 Christmas off-topic special seminar

1. Eric Galbraith, Especial Christmas Seminar: The 'Climate Emergency': scientific basis, impacts and possible solutions to the first planetary human problem, 17/12/2019

Chapter 7

Theses

7.1 PhD theses

7.1.1 Finished

Supervised by a member of the Institute. The students quated below reside at the Institute of Space Sciences.

1. Oltean, M. Title: 'Study of the Relativistic Dynamics of Extreme-Mass-Ratio Inspirals
   Supervisor: Sopuerta, C., Spallicci, A.
   Doctoral School: Universitat Autònoma de Barcelona

2. Rivas, F. Title: 'Thermo-elastic contributions to the acceleration noise on-board LISA Pathfinder'
   Supervisor: Nofrarias, M., Sopuerta, C.
   Doctoral School: Universitat Autònoma de Barcelona.

3. Alarcon, A., Cosmology with Galaxy Surveys.
   Supervisor: Gaztañaga, E.
   Doctoral School: Universitat Autònoma de Barcelona.

4. Porredon, A. M., Modeling galaxy clustering for precision cosmology.
   Supervisor: Crocce, M., Fosalba, P.
   Doctoral School: Universitat Autònoma de Barcelona.

7.1.2 Ongoing at the Institute

The titles below represent the topic of research, not necessarily the PhD thesis one. The students named below are all residing at the Institute.

1. Añez, N., Molecular cores, disk and jets: the effect of the magnetic field.
   Supervisor: Girart, J. M., Busquet, G.
   Doctoral School: Universitat de Barcelona.

2. Baroch, D., Rocky exoplanets and stellar activity with CARMENES
   Supervisor: Morales, J.C.
   Doctoral School: Universitat Autònoma de Barcelona

3. Lafarga Magro, M., Stellar activity and exoplanets of M dwarfs from CARMENES visible to near-infrared spectroscopy.
   Supervisor: Ribas, I.
   Doctoral School: Universitat Autònoma de Barcelona.

4. Lin, T., Models of pulsar wind nebuale.
   Supervisor: Torres, D. F.
   Doctoral School: Universitat Autònoma de Barcelona.

5. López-Zaragoza, J. P., Magnetic environment and magnetic-induced forces in LISA Pathfinder.
   Supervisor: Nofrarias, M.
   Doctoral School: Universitat Autònoma de Barcelona.

6. Mestre, E.,Estudios sobre la interacción plasma-campo magnetico en escenarios astrofísicos extremos.
   Supervisor: de Ona Wilhelmi, E., Torres, D. F.
   Doctoral School: Universitat Autònoma de Barcelona.

7. Montana, G, Heavy Hadrons in a Hot Dense Medium,
   Supervisor: Tolos, L.
   Doctoral School: Universitat de Barcelona.

8. Oliva, R., Techniques in Observational Cosmology.
   Supervisor: Elizalde, E.
   Doctoral School: Universitat de Barcelona.

9. Pocino, A., Cosmology with narrowband photometric redshifts.
   Supervisor: Castander, F. J.
   Doctoral School: Universitat Autònoma de Barcelona.

10. Rosich, A., Stellar activity effects on high-precision radial velocities: theory and observations.
    Supervisor: Ribas, I.
    Doctoral School: Universitat de Barcelona.

7.1.3 Ongoing elsewhere with supervision of Institute members

The titles below represent the topic of research, not necessarily the PhD thesis one. The students below may and generally do visit the Institute often.

1. Tanbakouei, S., Reflectance properties and mineralogy of asteroids and comets by using carbonaceous chondrites.
   Supervisor: Trigo-Rodriguez, J.M.
   Doctoral School: Universitat Autònoma de Barcelona.

2. Moreno-Ibáñez, M., Impact hazard associated with large meteoroids from disrupted asteroids and comets
   Supervisor: Trigo-Rodriguez, J.M.
   Doctoral School: Universitat Autònoma de Barcelona.

7.2 MsS theses

7.2.1 Finished

1. Carballosa, A.
   Title:' Probing cosmology and gravity theories through topological statistical descriptors'
   Director: Fosalba, P.
   Graduate School: Universitat Autònoma de Barcelona.

2. Cesar Ramírez Pérez
   Title: 'Constraining modified gravity models through the turnaround radius'
   Director: Odintsov, S. D., Elizalde, E.
   Graduate School: Universitat de Barcelona

3. Gerard Navo Pérez
   Title: 'Bounce cosmology from F(R,T) modified gravity'
   Director: Elizalde, E., Odintsov, S. D.
   Graduate School: Universitat de Barcelona

4. Gonzalez Reina, J.
   Title: 'On the relation between dark matter in halos and stellar mass in the Euclid Flagship galaxy mock'
   Director: Fosalba, P.
   Graduate School: Universidad Internacional de Valencia

5. Santiago Ubach Ramirez
   Title: 'Study of S-bearing molecules in high-mass star-forming regions'
   Director: Busquet, G., Girart, J. M.
   Graduate School: Universitat Autònoma de Barcelona

6. Comandran Casas, M.
   Title: ' Effective Field theories for chiral plasmas'
   Supervisor: Manuel, C.
   Graduate School: Universitat Autònoma de Barcelona

7. Jiang Ji Ho Zhang
   Title: 'Design of an antenna for the detection of kHz electromagnetic disturbances on-board LISA"
   Supervisor: Nofrarias, M; Ramos, J.J
   Graduate School: Univetsitat Politècnica de Catalunya

Chapter 8

Publications

8.1 Publications Summary

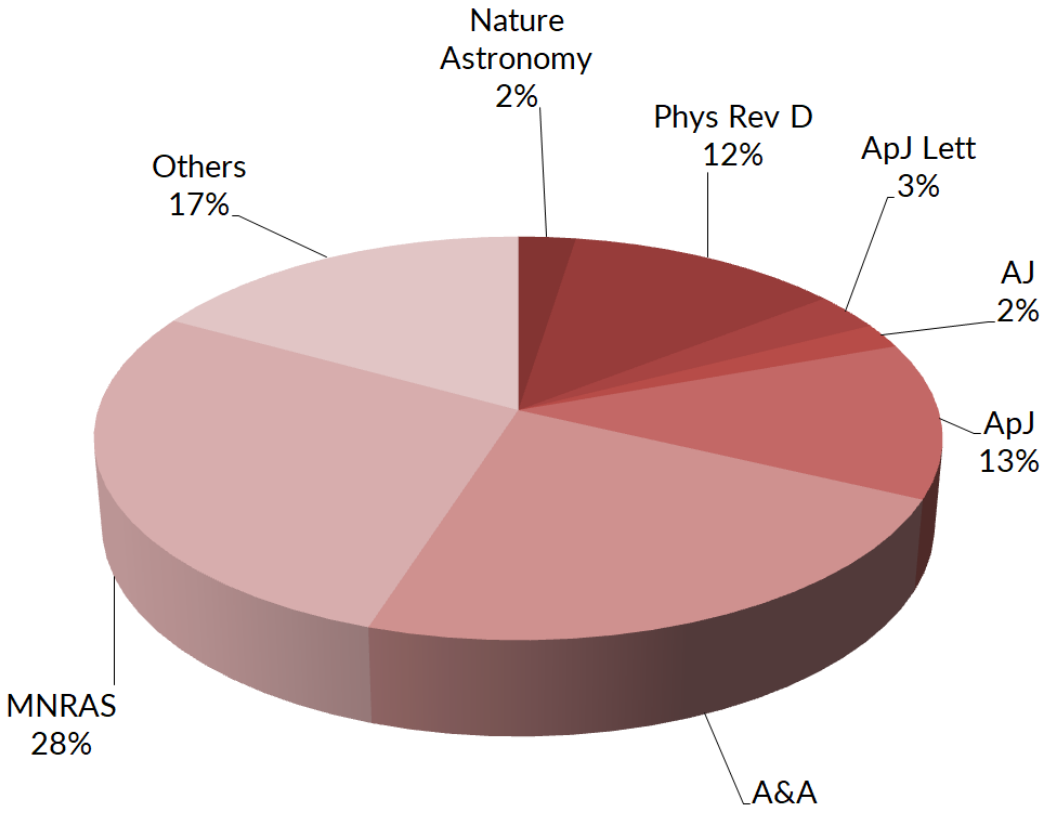


Figure 8.1: Distribution of our 200 publications in journals with peer review. All of these publications are directly accesible from an ADS-library linked from our web page. They are also individually listed below. More tan 85% of these publications are in 1^{st} quartile astrophysical journals (based on the quartiles classification of 2018)

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8.2 Publications List

ASTRONOMICAL JOURNAL

1. Padilla, C., **Castander, F. J.**,**Alarcon, A.**, et al., The Physics of the Accelerating Universe Camera, Astronomical Journal, 157, 6, 2019.

2. Stringer, K. M., Long, J. P., Macri, L. M., Marshall, J. L., Drlica-Wagner, A., Martínez-Vázquez, C. E., Vivas, A. K., Bechtol, K., Morganson, E., Carrasco Kind, M.,**Gaztañaga, E.**, **Serrano, S.**, et al, Identification of RR Lyrae Stars in Multi-band, Sparsely Sampled Data from the Dark Energy Survey Using Template Fitting and Random Forest Classification, Astronomical Journal, 158, 1, pp. 16, 2019.

3. Huber, D., Chaplin, W. J., Chontos, A., Kjeldsen, H., Christensen-Dalsgaard, J., Bedding, T. R., Ball, W., Brahm, R., Espinoza, N., Henning, T., **Serenelli, A.**, et al, A Hot Saturn Orbiting an Oscillating Late Subgiant Discovered by TESS, Astronomical Journal, 157, 6, pp. 245, 2019.

4. Banda-Huarca, M. V., Camargo, J. I. B., Desmars, J., Ogand o, R. L. C., Vieira-Martins, R., Assafin, M., da Costa, L. N., Bernstein, G. M., Carrasco Kind, M., Drlica-Wagner, A., **Fosalba, P.**,**Gaztañaga, E.**, **Serrano, S.**, et al, Astrometry and Occultation Predictions to Trans-Neptunian and Centaur Objects Observed within the Dark Energy Survey, Astronomical Journal, 157, 3, pp. 120, 2019.

ASTRONOMY & ASTROPHYSICS

5. **Busquet, G.**, **Girart, J. M.**, Estalella, R., Fernández-López, M., Galván-Madrid, R., Anglada, G., Carrasco-González, C., **Añez-López, N.**, Curiel, S., Osorio, **M.**, **Torrelles, J. M.**, et al, Unveiling a cluster of protostellar disks around the massive protostar GGD 27 MM1, ASTRONOMY & ASTROPHYSICS, 623, pp. L8, 2019.

6. **Serenelli, A.**, Rohrmann, R. D., Fukugita, M., Nature of blackbody stars, ASTRONOMY & ASTROPHYSICS, 623, pp. A177, 2019.

7. Dall'Olio, D., Vlemmings, W. H. T., Persson, M. V., Alves, F., Beuther, H., **Girart, J. M.**, Surcis, G., Torrelles, J. M., Van Langevelde, H. J., ALMA reveals the magnetic field evolution in the high-mass star forming complex G9.62+0.19, ASTRONOMY & ASTROPHYSICS, 626, pp. A36, 2019.

8. Juárez, C., Liu, H. B., **Girart, J. M.**, Palau, A.,**Busquet, G.**, Galván-Madrid, R., Hirano, N., Lin, Y., Extreme fragmentation and complex kinematics at the center of the L1287 cloud, ASTRONOMY & ASTROPHYSICS, 621, pp. A140, 2019.

9. Sánchez-López, A., Alonso-Floriano, F. J., López-Puertas, M., Snellen, I. A. G., Funke, B., Nagel, E., Bauer, F. F., Amado, P. J., Caballero, J. A., Czesla, S., **Ribas, I.**, **Anglada-Escudé, G.**, **Morales, J. C.**, et al, Water vapor detection in the transmission spectra of HD 209458 b with the CARMENES NIR channel, ASTRONOMY & ASTROPHYSICS, 630, pp. A53, 2019.

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Chapter 10

Summer School

The school run for five days, Monday 1st to Friday 5th July, 2019. The objective of this edition was to promote future research in Earth remote sensing, to connect future PhD students by research groups linked to the ICE and IEEE GRSS IFT Technical Committee, and to highlight the educational activities of the IEEE GRSS society. This was the first of an itinerant series (annual or biannual) of IFT-R3S editions, moving to different towns/continents, hosted by other In- strumentation and Future Technologies Technical Committee (IFT-TC) groups. Given the success of this first edition, 2019, New Zeeland will host the second one. The school was open to any interested person, but it focused on Master students, junior Ph.D. students and young professionals..

10.1 Participants

- The application to register to the Summer School was open from 4th February 2019 to 7th May 2019. The total number of applicants were 81, 42 applicants were selected to attend the school. The capacity of the venue is limited to 40-50 participants for a comfortable 1-week intense activity. The 81 applicants were affiliated to universities, institutions or companies from 31 different countries.

- The number of students in the Summer School were 42 distributed as:

Argentina: 1	**Italy:** 4	**Saudi Arabia:** 1
Australia: 1	**India:** 2	**Spain:** 5
Brazil: 1	**Japan:** 1	**Taiwan:** 1
Estonia: 1	**Netherlands:** 4	**Turkey:** 2
France: 2	**Philippines:** 1	**UK:** 3
Finland: 1	**Poland:** 2	**USA:** 2
Germany: 4	**Romania:** 2	**Zimbabwe:** 1

- The participants were gender balanced, 23 men and 19 women (54.8% and 45.2% respectively)

- The participants current occupation:

  Master Students: 12
  Ph.D. Students: 19
  Young Professionals and postdocs: 11

Figure 10.1: Participants and Lectures Summer School

10.2 Comments

- The final time table of the Summer School lessons and activities, including brief descriptions of each session, can be found in https://bit.ly/2Ihnqh4. It is also summarized below:

  Theoretical formation: 18 hours
  Practical exercises: 6 hours
  Visit to laboratories: 2 hours

- The technical and educational contents of the summer school was organized by the 'IEEE GRSS IFT-R3S Organizing Committee' with representatives of both IFT and ICE members. The duties of the Committee were:

  - To design the contents of the summer school, to find the lecturers and coordinate the contents each of them cover.
  - To make sure the costs of the lecturers and hands-on activities can be covered with the level of funding achieved.
  - To link and/report to the IEEE GRSS (AdCom) and Educational program.
  - To prepare or review the contents of the web page, announcements and any advertising/publicity/social network presence (communication issues).
  - To assign or prioritize the funding for student grants provided by ICE to the different students.

Chapter 11

Conferences organized by members

We list below only the conferences for which members of the Institute of Space Sciences acted as chairs or as main organizers.

1. PLATO STESCI Workshop III Place: Residencia Investidadores CSIC, Barcelona Dates: 19/11/2019 - 22/11/2019

2. Euclid Organization Unit for Simulations Workshop Place: Institute of Space Sciences; Alberto Lobo Room and Meeting Room 3rd Floor Dates: 13/11/2019 - 15/11/2019

3. 2nd International Conference on Symmetry (Symmetry 2019) Place: Centro de Ciencias de Benasque Pedro Pascual, Benasque, Spain. Dates: 01/09/2019 - 07/09/2019

4. eXTP Wide Field Monitor (WFM) Meeting + eXTP Science Requirements Meeting Place: Institute of Space Sciences; Alberto Lobo Room and Meeting Room 3rd Floor Dates: 09/07/2019 - 12/07/2019

5. Sant Cugat Forum on Astrophysics. Session VI: Workshop on Polarization in Protoplanetary Disks and Jets Place: Casa de la Cultura,Castellví 8, 08173 Sant Cugat del Vallès Date: 20/05/2019 - 24/05/2019

6. Workshop on Modified Gravity and Cosmology Place: ICE-CSIC, Campus UAB, Barcelona, Lobo Room Date: 07/05/2019 - 11/05/2019

Chapter 12

Contribution to Conferences and Seminars

1. A. Dielacher, H. Fragner, M. Moritsch, O. Koudelka, J. Wickert, M. Semmling, Cardellach, E., P. Hoeg, M. Martin-Neira , R. Walker , P. Beck, EXPECTED PERFORMANCE FOR GNSS-REFLECTOMETRY ON THE PRETTY CUBESAT , 7th International Colloquium on Scientific and Fundamental Aspects of GNSS, Zurich, Switzerland, Contributed talk, 04/09/2019, 06/09/2019

2. Andreas Dielacher, Heinz Fragner, Otto Koudelka, Peter Beck, Jens Wickert, Cardellach, E., P. Hoeg, HE ESA PASSIVE REFLECTOMETRY AND DOSIMETRY (PRETTY) MISSION, IGARSS 2019, Yokohama, Japan, Contributed talk, 28/07/2019, 02/08/2019

3. Baroch, D., Actividad estelar con CARMENES: el Índice Cromático, Ciencia presente y futura con CARMENES & 1er encuentro EXONET, Granda, Contributed talk, 20/02/2019, 22/02/2019

4. Busquet, G., A deep synoptic radio survey of high-mass precursors in infrared dark clouds, SKA 2019 General Science Meeting and Key Science Workshop, Alderley Edge, Manchester, Poster, 08/04/2019, 12/04/2019

5. Busquet, G. A deep synoptic radio survey toward high-mass precursors in infrared dark clouds. Spain in SKA! Instituto de Astrofísica de Andalucía, Granada (Spain). 10/06/2019-11/06/2019

6. Cardellach, E., Overview of PAZ Results, EUMETSAT/ESA Radio Occultation Science Advisory Group (RO SAG) Meeting 06, Darmstadt, Germany , Invited talk, 07/05/2019, 08/05/2019

7. Cardellach, E., Sensing hydrometeors using polarimetric GNSS radio occultation signals aboard the PAZ satellite, NASA/JPL SVCP Seminar, Padasena, CA, USA, Invited talk, 27/03/2019, 27/03/2019

8. Cardellach, E., Science potential of polarimetric LEO-LEO microwave signals for precipitation profiling , Forum on Exploring greenhouse gases, water and climate changes by LEO-LEO occultation, Beijing, China, Invited talk, 24/07/2019, 25/07/2019

9. Cardellach, E., Fabra, F., Li, W., Nan, Y., Ribó, S., Rius, A., Overview of the GNSS Research at IEEC-CSIC, 8th Joint ESA-China GNSS-R Working Group Meeting, Valencia, Invited talk, 25/09/2019, 27/09/2019

10. Cardellach, E., Li, W., Rius, A., J. Wickert, M. Semmling, F. Zus, C. Ruf, Precise Ocean Altimetry Using GNSS-R Signals: Grazing Angle Carrier Phase Delay Altimetry from CyGNSS Mission, ESA Living Planet Symposium 2019, Milan, Contributed talk, 12/05/2019, 17/05/2019

11. Cardellach, E., Li, W., Rius, A., J. Wickert, M. Semmling, F. Zus, C. Ruf, Precise Ocean Altimetry Using GNSS-R Signals: Grazing Angle Carrier Phase Delay Altimetry from CyGNSS Mission, ESA Living Planet Symposium 2019, Milan, Contributed talk, 12/05/2019, 17/05/2019

12. Cardellach, E., Li, W., Rius, A., M. Semmling, J. Wickert, F. Zus, C. Ruf, FIRST EVIDENCES OF SPACEBORNE CARRIER PHASE ALTIMETRY USING GNSS REFLECTED SIGNALS AT GRAZING ANGLES OF OBSERVATION OVER OPEN SEA WATER, IGARSS 2019, Yokohama, Japan, Contributed talk, 28/07/2019, 02/08/2019

13. Cardellach, E., Li, W., Rius, A., Semmling, M., Wickert, J., Zus, F., Ruf, C., Spaceborne Carrier Phase Altimetry Using GNSS Reflected Signals At Grazing Angles Of Observation Over Open Sea Water , GNSS+R 2019, Benevento, Italy, Contributed talk, 20/05/2019, 22/05/2019

14. Cardellach, E., Oliveras, S., Rius, A., Tomas, S., et al., Polarimetric GNSS RO aboard the PAZ satellite: status of the ROHP-PAZ experiment, Joint 6th ROM SAF User Workshop and 7th IROWG Workshop, Helsingør (Elsinore), Denmark, Invited talk, 18/09/2019, 25/09/2019

15. Cardellach, E., R Padulles, CO Ao, F Cerezo, J Clapp, GW Franklin, D Hunt, BA Iijima, D Kuang, TK Meehan, Oliveras, S., Rius, A., WS Schreiner, S Sokolovskiy, S Tomas, M de la Torre Juarez, J Turk, T Vanhove, J Weiss, W Xia-Serafino, Y Yoon, Z Zeng, Sensing Heavy Precipitation Using a Bistatic 'Radar of Opportunity' Aboard the PAZ Satellite: Early Results From Commissioning Phase, ESA Living Planet Symposium 2019, Milan, Poster, 12/05/2019, 17/05/2019

16. Cardellach, E., S. Nghiem, Li, W., C. Ruf, Potential for GNSS Reflectometry to Sense Wetland Water underneath Dense Mangrove Canopies: CyGNSS Spaceborne Data over the Can Gio Biosphere Reserve Experimental Campaign, Satellite Observations of Environmental Changes from Rural to Mega Urban Areas – Impacts and Implications, Hanoi, Vietnam, Invited talk, 17/07/2019, 17/07/2019

17. Cardellach, E., S. V. Nghiem, Li, W., C. Ruf, Potential for GNSS Reflectometry to Sense Wetland Water underneath Dense Mangrove Canopies: TDS-1 and CyGNSS Spaceborne Data over the Can Gio Biosphere Reserve Experimental Campaign, ESA Living Planet Symposium 2019, Milan, Poster, 12/05/2019, 17/05/2019

18. Cardellach, E., Tomás, S., Oliveras, S., Rius, A., C.O. Ao, F.J. Turk, M. la Torre-Juárez, R. Padullés, B.A. Iijima, G.W. Franklin, T.K. Meehan, D.és3, B.A. Iijima3, G.W.Kuang, K.-N. Wang , The ROHP-PAZ experiment: sensing heavy rain from Space using L-band signals of opportunity at limb-looking forward scattering geometry , PIERS 2019, Rome, Invited talk, 17/06/2019, 20/06/2019

19. de Angelis, et al. including, Hernanz, M., All-Sky-ASTROGAM: a MeV Companion for Multimessenger Astrophysics, 36th International Cosmic Ray Conference - ICRC2019, Madison, WI (USA), Poster, 24/07/2019, 01/08/2019

20. E. Mestre, E. de Oña Wilhelmi, R. Zanin, D. F. Torres, The Crab nebula and pulsar seen through the Cherenkov Telescope Array, CTA 1st Science symposium, Bologna, Poster, 06/05/2019, 09/05/2019

21. Elizalde, E., The Universe symmetry and its accelerated expansion: history and present issues, The 2nd International Conference on Symmetry (Symmetry 2019), Benasque, Invited talk, 01/09/2019, 07/09/2019

22. Fabra, F., Cardellach, E., Li, W., Ribó, S., Rius, A., Martin-Neira, M., Towards precise synoptic altimetry by means of GNSS-R, GNSS+R 2019, Benevento, Italy, Contributed talk, 20/05/2019, 22/05/2019

23. Fabra, F., Li, W., Cardellach, E., Ribó, S., Rius, A., Remote Sensing Using Reflected GNSS Signals: Activities at IEEC, The 8th CSA-IAA Conference on Advanced Space Technology, Shanghai, Invited talk, 03/09/2019, 06/09/2019

24. Fabra, F., Cardellach, E., Li, W., Ribó, S., Rius, A., Martin-Neira, M., Towards precise synoptic altimetry by means of GNSS-R, GNSS+R 2019, Benevento, Italy, Contributed talk, 20/05/2019, 22/05/2019

25. Fabra, F., Li, W., Cardellach, E., Ribó, S., Rius, A., Remote Sensing Using Reflected GNSS Signals: Activities at IEEC, The 8th CSA-IAA Conference on Advanced Space Technology, Shanghai, Invited talk, 03/09/2019, 06/09/2019

26. Girart, J. M., Dust polarization at cm wavelengths, New Science enabled by New Technologies in the SKA Era, Cheshire, UK, Poster, 08/04/2019, 12/04/2019

27. Girart, J. M., ALMA polarization observations of protoplanetary disks, Summer Protoplanetary Disk Workshop (SPPD2019), Santiago (Chile), Contributed talk, 22/01/2019, 23/01/2019

28. H. Fragner, A. Dielacher, M. Moritsch, P. Hoeg, J. Wickert, Cardellach, E., O. Koudelka, P. Beck, R.Walker, F.P. Lissi, M. Martin-Neira, The passive Reflectometer on Board of PRETTY, Advanced Remote Sensing Instruments (ARSI) 2019, Noordwijk, Netherlands, Contributed talk, 11/11/2019, 13/11/2019

29. H. Lyu, M. Hernández-Pajares, M. Nohutcu, Garcia-Rigo, A., Enric Monte-Moreno, Cardellach, E., Blanch, E., Contributions to GNSS ionospheric mapping function and Truncated radio occultation modeling , International Reference Ionosphere 2019 Workshop (IRI 2019), Nicosia, Cyprus, Contributed talk, 09/09/2019, 13/09/2019

30. Heinrich Fragner, Andreas Dielacher, Michael Moritsch, Franz Zangerl, Peter Beck, Otto Koudelka, Per Hoeg, Jens Wickert, Cardellach, E., Manuela Wenger, Andreas Hörmer, Reinhard Zeif, Franz Teschl, Manuel M. Neira, Maximilian Semmling, Roger Walker, Recycling GPS signals and radiation monitoring: the two payloads onboard PRETTY, CubeSats and SmallSats for Remote Sensing III, part of SPIE Optical Engineering and Applications, San Diego, CA, USA, Contributed talk, 11/08/2019, 12/08/2019

31. Hernanz, M., Novae as Gamma-ray sources from radioactivities and particle acceleration, 17th HEAD (High Energy Astrophysics Division of the American Astronomical Society) Divisional Meeting, Monterrey (CA, EEUU), Contributed review, 17/03/2019, 21/03/2019

32. Hernanz, M., eXTP (enhanced X-ray Timing and Polarimetry): an X-ray mission in collaboration with China already in Phase B, Spanish X-ray Astronomy 2019 (SXA2019), Alicante, Contributed talk, 26/11/2019, 27/11/2019

33. Hernanz, M., Novae as X- and gamma-ray sources: insights on thermonuclear burning and mass ejection, Lorentz Center Workshop "Bursting the Bubble: Connecting Thermonuclear Burst Research to a Wider Community", Leiden (Netherlands), Invited review, 24/06/2019, 28/06/2019

34. Hunt, D., Sokolovskiy, S., Sleziak-Sallee, M., VanHove, T., Weiss, J.P., Cardellach, E., Oliveras, S., PAZ Neutral Atmosphere Radio Occultation Retrieval Processing, Joint 6th ROM SAF User Workshop and 7th IROWG Workshop, Helsingør (Elsinore), Denmark, Contributed talk, 18/09/2019, 25/09/2019

35. J. Wickert, H. Fragner, P Beck, O Koudelka, Cardellach, E., A Dielacher, P Hoeg, Li, W., M Martin-Neira, Rius, A., M. Semmling, F Zangerl, F Zus, PRETTY: Cubesat for precise altimetry using navigation satellites, ESA Living Planet Symposium 2019, Milan, Poster, 12/05/2019, 17/05/2019

36. J. Wickert, H. Fragner, P. Beck, O. Koudelka, Cardellach, E., A. Dielacher, P. Hoeg, Li, W., M.M. Neira, Rius, A., M. Semmling, F. Zangerl, F. Zus, PRETTY: Cubesat for precise altimetry using navigation satellites, 27th IUGG General Assembly (IUGG 2019), Montreal, Canada, Poster, 08/07/2019, 18/07/2019

37. J. Wickert1, H. Fragner, P. Beck, O. Koudelka, Cardellach, E., A. Dielacher, P. Hoeg, Li, W., M. Martin-Neira, Rius, A., et al, PRETTY: Cubesat for precise altimetry using navigation satellites, GNSS+R 2019, Benevento, Italy, Contributed talk, 20/05/2019, 22/05/2019

38. KN. Wang, C. O. Ao, R. Padulles, F. J. Turk, M. de la Torre Juarez, B. A. Iijima, D. Kuang, Cardellach, E., Oliveras, S., J. S. Haase, Retrieving Heavy Precipitation from Polarimetric Radio Occultation Observations with a Least Squares Approach, American Meteorological Society 99th Annual Meeting 2019, Phoenix, USA, Contributed talk, 06/01/2019, 10/01/2019

39. Li, W., Cardellach, E., Fabra, F., Ribó, S., Rius, A., Assessing Spaceborne GNSS-R Ocean Altimetry Precision using CYGNSS Data, IEEE GNSS+R 2019, Benevento, Poster, 20/05/2019, 22/05/2019

40. Li, W., Cardellach, E., Fabra, F., Ribó, S., Rius, A., APPLICATIONS OF SPACE-BORNE GNSS-R OVER INLAND WATERS AND WETLANDS, IGARSS 2019, Yokohama, Japan, Invited talk, 28/07/2019, 02/08/2019

41. Li, W., Cardellach, E., Fabra, F., Ribó, S., Rius, A., Martin-Neira, M., Sea ice thickness derived from GNSS-R altimetry: Demonstration with the TDS-1 data, Living Planet Symposium 2019, Milano, Poster, 13/05/2019, 17/05/2019

42. Li, W., Cardellach, E., Ribó, S., Rius, A., F. Fabra, Explorations of Spaceborne GNSS-R Data from TDS-1 and CYGNSS Missions , 8th Joint ESA-China GNSS-R Working Group Meeting, Valencia, Invited talk, 25/09/2019, 27/09/2019

43. López-Zaragoza, J. P., Magnetic Diagnostics on LPF and LISA, LISA Consortium Meeting IV, Gainesville, Contributed talk, 28/04/2019, 04/05/2019

44. López-Zaragoza, J. P., Magnetic experiments onboard LPF, 13th Amaldi conference on GWs, Valencia, Contributed talk, 08/07/2019, 12/07/2019

45. Lyu, H., Hernández-Pajares, M., Monte-Moreno, E., Cardellach, E., Two methods of electron density retrieval from truncated ionospheric radio occultation data, Joint 6th ROM SAF User Workshop and 7th IROWG Workshop, Helsingør (Elsinore), Denmark, Contributed talk, 18/09/2019, 25/09/2019

46. M. Hernández-Pajares, G. Olivares-Pulido, À. Aragón-Àngel, F. dos Santos Prol, H. Lyu, E. Monte-Moreno, Cardellach, E., M. Garcia-Fernàndez, Rius, A., R. Notarpietro, A. von Engeln, D.R. Themens, Garcia-Rigo, A., P. de Oliveira Camargo, M.T. de Assis Honorato Muella, Recent progress in Linear Vary-Chapman (LVC) modelling of the electron density, International Workshop on GNSS Ionosphere (IWGI2019), Neustrelitz, Germany, Invited talk, 23/09/2019, 25/09/2019

47. M. Semmling, K Balidakis, G Stienne, S Reboul, Cardellach, E., Li, W., J Wickert, H Schuh, GNSS amplitude estimation and its application to coherently reflected signals for sea ice remote sensing, ESA Living Planet Symposium 2019, Milan, Poster, 12/05/2019, 17/05/2019

48. Odintsov, S. D., Modified gravity: an overview, Siberian Spring Cosmology, TSPU, Tomsk, Russia (1-2 March), Invited review, 01/03/2019, 02/03/2019

49. Odintsov, S. D., Modified gravity and cosmology, Symmetry 2019, Benasque, Invited review, 01/09/2019, 07/09/2019

50. Odintsov, S. D., Modified gravity and cosmology: an overview, int seminar on gravitation and cosmology, Sant-Petersburg, Invited review, 23/06/2019, 29/06/2019

51. Odintsov, S. D., Modified gravity and cosmology, 10th math physics meeting, Belgrade, Invited review, 10/09/2019, 14/09/2019

52. Oltean, M., The self-force problem in general relativity, Humboldt Colloquium: Research without Borders – Alexander von Humboldt's Legacy Today, Madrid 2019, Madrid, Poster, 12/04/2019, 13/10/2019

53. Oltean, M., Epp, R., Sopuerta, C., Spallicci, A., Mann, R., The Motion Of Localized Sources In General Relativity: Gravitational Self-Force From Quasilocal Conservation Laws, 22nd International Conference on General Relativity and Gravitation / 13th Edoardo Amaldi Conference on Gravitational Waves, Valencia, Contributed talk, 07/07/2019, 12/07/2019

54. Oltean, M., Epp, R., Sopuerta, C., Spallicci, A., Mann, R., On the equations of motion for extreme-mass-ratio inspirals, 9th Iberian Gravitational Waves Meeting, Santiago de Compostela, Contributed talk, 03/06/2019, 05/06/2019

55. Padullés, R., Cardellach, E., F. J. Turk, C. O. Ao, K. N. Wang, M. de la Torre Juarez, Sounding Heavy Precipitating Vertical Cloud Structures using Polarimetric Radio Occultations, American Geophysical Union (AGU) Fall Meeting 2019, San Francisco, CA, USA, Contributed talk, 09/12/2019, 13/12/2019

56. Padullés, R., F. J. Turk, C. O. Ao, M. de la Torre Juarez, K. Wang, B. A. Iijima, Cardellach, E., S. Tomas, Oliveras, S., Rius, A., Sensing of Heavy Precipitation aboard the PAZ Satellite: Validation of Polarimetric Radio Occultation Precipitation Observations with GPM Constellation Products, American Meteorological Society 99th Annual Meeting 2019, Phoenix, USA, Contributed talk, 06/01/2019, 10/01/2019

57. Padullés, R., J. Turk, C. O. Ao, M. de la Torre Juarez, K. Wang, B. A. Iijima, Cardellach, E., Oliveras, S., S. Tomas, Rius, A., Sensing Heavy Precipitation with Polarimetric Radio Occultations Aboard the PAZ Satellite: A New View of Precipitation and Water Vapor, Joint EUMETSAT / AMS / NOAA Conference 2019, Boston, MA, USA, Poster, 28/09/2019, 04/10/2019

58. Padullés, R., Ao, C.O., Turk, F.J., de la Torre Juárez, M., Iijima, B., Wang, K.N., Cardellach, E., Calibration and Validation of the Polarimetric Radio Occultation and Heavy Precipitation onboard PAZ experiment and potential scientific applications, Joint 6th ROM SAF User Workshop and 7th IROWG Workshop, Helsingør (Elsinore), Denmark, Contributed talk, 18/09/2019, 25/09/2019

59. Ribó, S., Cardellach, E., Fabra, F., Li, W., Rius, A., Measuring Surface Doppler Velocities using Opportunistic Signals at X-Band, Living Planet Symposium 2019, Milano, Contributed talk, 13/05/2019, 17/05/2019

60. Rivas, F., Thermal environment onboard the LISA Pathfinder mission, IV LISA CONSORTIUM, Gainesville, Contributed talk, 28/04/2019, 04/05/2019

61. Rivas, F., Data and Diagnostics Subsystem onboard the LISA Pathfinder mission, 9th Iberian Gravitational Waves Meeting, Santiago de Compostela, Contributed talk, 03/06/2019, 05/06/2019

62. Rivas, F., Temperature-induced effects on LISA Pathfinder: Thermo-elastic and thermo-optical effects, 13th Edoardo Amaldi Conference on Gravitational Waves, Valencia, Poster, 08/07/2019, 12/07/2019

63. Roma-Dollase, D., Nofrarias, M., Ramos, J., Albich, K. , Sanjúan, J. , Enhanced temperature measurement concept for LISA, 22nd International Conference on General Relativity and Gravitation 13th Edoardo Amaldi Conference on Gravitational Waves, Valencia, Poster, 08/07/2019, 12/07/2019

64. Roma-Dollase, D., Nofrarias, M., Sierra-Roig, C., Ramos, J., Ribas, C., A distributed chip-scale magnetic diagnostic subsystem, 22nd International Conference on General Relativity and Gravitation 13th Edoardo Amaldi Conference on Gravitational Waves, Valencia, Poster, 08/07/2019, 12/07/2019

65. Shah, R, Garrison, J , Cardellach, E., Ribó, S., Ho, S.C, Li, Z., Song, Y. T., Reflected Signals of Opportunity Technique for Ocean Applications, OceanObs 2019, Honolulu, Hawaii, USA, Poster, 16/09/2019, 20/09/2019

66. Son Nghiem, Donald Perovich, Christopher Polashenski, Stephen Lowe, Shah Rashmi, Anthony Mannucci, Adriano Camps, Cardellach, E., Leung Tsang, Jiyue Zhu, Shurun Tan, Polar sea thickness and melt pond fraction measurements with multi-frequency bistatic radar polarimetric reflectometry, IGARSS 2019, Yokohama, Japan, Contributed talk, 28/07/2019, 02/08/2019

67. Sopuerta, C., Impact of LISA on AGN Research, V Meeting of AGN research in Spain, Santander, Invited talk, 12/07/2019, 12/07/2019

68. Sopuerta, C., New approaches to the self-force problem for Extreme-Mass-Ratio Inspirals, 30th Texas Symposium on Relativistic Astrophysics, Portsmouth, Contributed talk, 15/12/2019, 21/12/2019

69. Sopuerta, C., New approaches to the self-force problem for Extreme-Mass-Ratio Inspirals, 30th Texas Symposium on Relativistic Astrophysics, Portsmouth, Contributed talk, 15/12/2019, 21/12/2019

70. Tatischeff, V., et al.including, Hernanz, M., Isern, J., All-Sky-ASTROGAM: The MeV Gamma-Ray Companion to Multimessenger Astronom, 12th INTEGRAL conference "INTEGRAL looks AHEAD to Multimessenger astronomy, Geneva (Switzerland), Invited talk, 11/02/2019, 15/02/2019

71. Tolos, L., Hyperon Interaction in Dense Nuclear Matter and Link to Neutron Stars, SQM2019, Invited review, 13/06/2019

72. Tolos, L., Heavy excited baryons with heavy-quark spin symmetry, ECT* Trento Workshop, Invited talk, 06/10/2019

73. Tolos, L., EoS in neutron stars - recent results on cooling and tidal deformabilities, Neutron Star Theory, Madrid, Contributed talk, 10/10/2019

74. Wang, K.-N., Ao, C.O., Padullés, R., Turk, F.J., de la Torre Juárez, M., Cardellach, E., A study on the effects of heavy precipitation on polarimetric radio occultation (PRO) bending angle observations, Joint 6th ROM SAF User Workshop and 7th IROWG Workshop, Helsingør (Elsinore), Denmark, Poster, 18/09/2019, 25/09/2019

75. Wilson-Hodge, Colleen A., Ray, Paul S., Maccarone, Thomas J., Chakrabarty, Deepto, et al. including, Hernanz, M., STROBE-X: X-ray Timing & Spectroscopy on Dynamical Timescales from Microseconds to Years, 233 American Astronomical Society, AAS Meeting, Seattle, Washington, EEUU, Poster, 06/01/2019, 10/01/2019

Chapter 13

Awards to our personnel

1. Fundación Real Academia de Ciencias al Joven Talento Científico Femenino, Dra. Nanda Rea.
2. Premi ciutat de Barcelona, Dr. Ignasi Ribas.
3. CSIC Distinction of Merit, Prof. Emilio Elizalde.
4. Silver sign of TUSUR University Tomsk, Prof. S.D. Odintsov.
5. Medal For Achievments of TUSUR University, Tomsk , Prof. Sergei D Odintsov.
6. Tomsk Regional Government Silver medal For Achievments, Prof. Sergei D Odintsov.
7. Honorary Professorship Award of Tomsk State Pedagogical University in relation with 60 years birthday, Prof. Sergei D Odintsov.
8. Honorary Professorship of Tomsk State Pedagogical University, Prof. Sergei D Odintsov.
9. Distinguished referee of EPL 2018, Prof. Sergei D Odintsov.

Chapter 14

Projects

14.1 Competitive Funding Summary

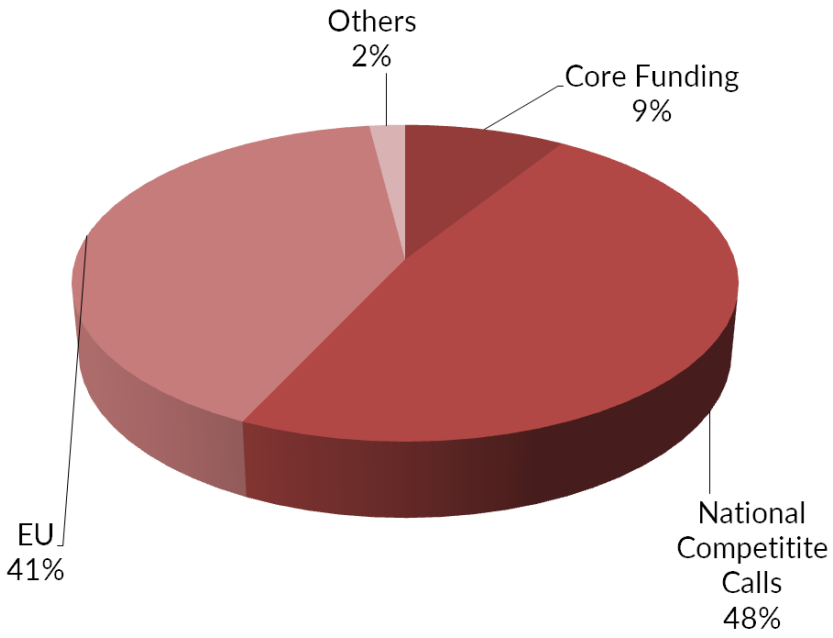

Figure 14.1: Distribution of our new projects per funding agencies.

Without including salaries of our researchers and other personnel, we have received:

- **Core funding from CSIC** = 0.46 MEuros (Including non-recurrent budgetary additions, not including personnel salaries)
- **In-kind funding from IEEC** = 0.10 MEuros (Estimated from counting additional managerial, communications, and system manager support beyond our CSIC funding core)
- **Competitive funding granted in 2019**= 3.75 MEuros

14.2 New projects in 2019

Table 14.1: Projects that were obtained during 2019

Project Code	Title	IPs	Funding Source
RTI2018-099008-B-C22	Sensing with pioneerring opportunistic techniques	Cardellach, E.	MICINN, Spain
PGC2018-095512-B-I00	Estrellas de neutrones estudiando el universo mas extremo con observaciones, simulaciones y planeamiento inteligente de nueva instrumentación	Rea, N.	MICINN, Spain
PGC2018-097374-B-I00	Propiedades físico-químicas de asteroides y cometas peligrosos a partir de observaciones y el estudio de sus meteoritos	Trigo-Rodriguez,J.M	MICINN, Spain
PGC2018-102021-B-I00	Cosmología con mapas de galaxias	Gaztañaga, E.	MICINN, Spain
EQC2019-005664-P	Equipamiento científico para la realización y mejora de simulaciones en astrofísica y cosmología	Torres, D.F.	MICINN, Spain
ERC consolidator817661	Magnetar Census: the impact of highly magnetic neutron stars in the explosive and transient Universe	Rea, N.	Europe
RYC-2017-22489	Ayuda para la contratación de personal investigador RyC 2017	Anglada, G	MICINN, Spain
RYC-2017-21810	Ayuda para la contratación de personal investigador RyC 2017	Patruno, A.	MICINN, Spain
FJCI-2017-31628	Ayudas Juan de la Cierva-formación 2017	Khurshuyan, M.	MICINN, Spain

Table 14.2: Projects that were obtained during 2019, Continued.

Project Code	Title	IPs	Funding Source
FJCI-2017-34546	Ayudas Juan de la Cierva-formación 2017	Coti Zelati, F.	MICINN, Spain
FSSCAT	FSSCAT Validationexperiment in MOSAIC	Cardellach,E.	ESA
RFQ	RFQ 1300054384 GNSS-R	Cardellach,E.	ESA
AO/1-9415/18/NL/BW	LISA Enhanced Temperature Subsystem (LETS)	Nofrarias, M	European Space Agency (ESA)

14.3 Active projects in 2019

Table 14.3: Projects that were active during 2019

Project Code	Title	IPs	Funding Source
PHAROS	The multi-messenger PHysics and Astrophysics of neutROn Stars	Rea, N.	H2020, EU
734374	LACEGAL, Latin American Chinese European GALaxy Formation network	Gaztañaga,E.	H2020, EU
ESP 2017 82674	E-ASTROGAM y e-XTP, dos oportunidades de misiones espaciales para diagnosticar explosiones estelares	Hernanz, M.	MINECO, Spain
AYA 2017 84390-C-2-R	Jet estelares, discos y campos magneticos. Ciencia para el SKA y contribución al diseño de phased array feeds	Girart. J.M.	MINECO, Spain
FIS2016-76363-P	UNIVAZ - Models for the accelerated expansion of the Universe, quantum fluctuations and zeta regularization	Elizalde, E., Odintsov, S. D.	MINECO, Spain

Table 14.4: Projects that were active during 2018, Continued.

Project Code	Title	IPs	Funding Source
ESP2017-90908-REDT	Cartografiados cosmicos y estructura a gran escala del universo	Gaztañaga,E	MICINN, Spain
AYA2017-90833-REDT	Red española de exoplanetas	Ribas, I	MICINN, Spain
AYA2017-92402-EXP	La bestia interior y exterior: Aceleración y emisión de gaps de púlsares y modelos morfologicos-espectrales de sus nebulosas	Torres, D	MICINN, Spain
2018 SGR 247	Excellence Group Grant	Elizalde, E.	AGAUR, Generalitat de Catalunya
2018 SGR 885	Excellence Group Grant	Fosalba, P.	AGAUR, Generalitat de Catalunya
2018 SGR 1131	Excellence Group Grant	Ribas, I.	AGAUR, Generalitat de Catalunya
2018 SGR 1383	Excellence Group Grant	Rea, N.	AGAUR, Generalitat de Catalunya
2018 SGR 1469	Excellence Group Grant	Sopuerta, C.	AGAUR, Generalitat de Catalunya
I-LINK1238	Towards an Intelligent Multi-facility Scheduler to Optimize Multi-frequency Observations	Torres, D.F.	CSIC

Table 14.5: Projects that were active during 2018, Continued.

Project Code	Title	IPs	Funding Source
201850E099	Cross-field research in space sciences	Torres, D.F	CSIC
201850I084	Asteroseismología con TESS	Serenelli, A.	CSIC
201880I020	La ciencia de LISA: Desarrollos para el futuro observatorio espacial de ondas gravitatorias de la Agencia Espacial	Sopuerta, C.	CSIC
776247	Enabling Weak lensing Cosmology	Castander, Fco.	EU
ESA PO N.5001025474	GNSS-R in MOSAiC	Cardellach, E.,	ESA
EUMETSAT funded	Radio Occultation Meteorology Satellite Application Facility, 3rd Continuous Development and Operations Phase (ROM-SAF CDOP-3)	Others	

Chapter 15

Scientific Press Releases in 2019

15.1 The Dark Energy Survey completes the six-year data acquisition

January 10, 2019

After in-depth exploration of a quarter of the southern sky for six years and cataloging hundreds of millions of distant galaxies, the Dark Energy Survey (DES) completes data collection on January 9.

Figure 15.1: Observatori de Cerro Tololo (Xile) Crèdit: Fermilab

The project is an international collaboration that began mapping a 5000-square-meter region of the sky on August 31, 2013, with the aim of understanding the nature of dark energy, the mysterious force that is accelerating. the expansion of the universe. DES scientists have taken data for 758 nights over six years using the DECam (Dark Energy Camera), a 520-megapixel digital camera funded by the U.S. Department of Energy (DoE). and the Ministry of Science, Innovation, and Universities of Spain, among other international organizations. Researchers at the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), the Institute of Space Sciences (ICE-CSIC)

/ Institute for Space Studies of Catalonia (IEEC), the Institute for High Energy Physics (IFAE) and the Institute of Theoretical Physics (UAM-CSIC) integrate the Spanish contribution to the project, DES-Spain. The camera is mounted on the 4-meter White Telescope, located at the Inter-American Observatory of Cerro Tololo, in the Chilean Andes, and which belongs to the National Science Foundation of the U.S.A. The DES-Spain collaboration played a leading role in the construction of DECam, as it was responsible for the design, verification, construction, and installation of most of the reading electronics.

All these nights, scientists have accumulated data from more than 300 million distant galaxies. More than 400 scientists from 26 institutions around the world are contributing to the implementation of this project, which is led by the DoE's Fermilab (National Accelerator Laboratory). The collaboration has already produced over 200 scientific articles, and will publish many more.

DES is one of the most responsive and comprehensive maps ever made. DECam is able to see the light of galaxies billions of light-years and with unprecedented quality.

The mapper has generated 50 Terabytes of information (that is, 50 million Megabytes) of information over the six years of operation. This data is stored at the National Center for Supercomputing Applications (NCSA), located at the University of Illinois at Urbana-Champaign.

Now the central activity of the collaboration will be focused on data analysis. DES has already published a complete series of scientific articles based on data taken during the first year, and scientists are now focusing on analyzing the rich already cataloged data set for the first three years of the campaign, looking for new clues to the nature of dark energy. "DES is the first major mapping of galaxies to study in detail the properties of dark matter. It has been a great success to have collected such a huge and accurate amount of data. Now it remains to analyze them. It may contain the signal of some important discovery. " says Eusebio Sánchez, the researcher responsible for DES at CIEMAT. For his part, Enrique Gaztañaga, the researcher responsible for DES at the ICE-CSIC / IEEC, adds that "DES-Spain was the first international collaboration to found DES more than 15 years ago. During this time we have had the opportunity to gain experience in very different aspects in an international frontline project. These include instrumentation, organization, funding, and science. It was our first project together and was the seed for the DES-Spain team to be able to tackle new challenges. Start and even lead other equally ambitious projects, such as EUCLID (euclid-ec.org), PAUS (pausurvey.org) or DESI (desi.lbl.org). "

DES collaboration will continue to publish scientific results from stored data. Scientists presented the latest findings in a special session held at the American Astronomical Society (AAS) 's winter meeting in Seattle on January 8. DES also organizes an interactive event from 23:30 to 00:30 in the morning from January 9 to 10 at the NOAO booth in the main exhibition hall of the AAS meeting, which includes a direct connection to the observatory, where scientists are preparing for one last night of observation.

Some of the most outstanding scientific results obtained by DES so far are:

The most accurate measurement of the structure of dark matter in the Universe, which, when compared to results obtained using background cosmic radiation, allows scientists to reconstruct the evolution of the cosmos. (http://news.fnal.gov/2017/08/dark-energy-survey-reveals-accurate-measurement-dark-matter-structure-universe) The discovery of many new satellite dwarf galaxies in our own Milky Way galaxy, which provides new tests for current dark matter theories (http://news.fnal.gov/2015/08/dark-energy-survey-finds-more-celestial-neighbors).

Creating the most accurate map of dark matter ever obtained in the Universe `http://news.fnal.gov/2017/08/dark-energy-survey-reveals-accurate-measurement-dark-matter-structure-universe`.
The discovery of the most distant known supernova `https://penntoday.upenn.edu/news/astronomers-reveal-secrets-most-distant-supernova-ever-detected`.Publicly distributing data from the first three years of mapping, which allows astronomers around the world to make discoveries and additional science.`http://news.fnal.gov/2018/01/dark-energy-survey-publicly-releases-first-three-years-of-data`.

The first optical counterpart to a gravitational emission event, in a two-star neutron collision that occurred 130 million years ago. `http://news.fnal.gov/2017/10/scientists-spot-explosive-counterpart-ligovirgos-latest-gravitational-waves`. DES was one of the mappers in the sky to detect the source of gravitational waves in visible light, which opens the door to a new type of astronomy.
"By analyzing only one-fifth of the data, DES has already achieved some of the most accurate cosmological measurements made so far. By analyzing all the data over the coming years, DES will submit the cosmological model in force - which assumes that dark energy is due to the cosmological constant proposed and then discarded by Einstein - to the hardest test ever. he has faced. " says Ramon Miquel, chief researcher at DES at IFAE. Juan García-Bellido, lead researcher at DES at IFT-UAM / CSIC, says that "It's exciting to have been able to participate, thanks to DESCam, in a discovery like Kilonova, which launched a new era, the of Multimedia Messenger Astronomy, and that has allowed determining independently the rate of expansion of the Universe ".

DES recently published its first supernovae-based cosmological results (207 of them with spectroscopic tracking for the first three years of data), using a method that provided the first evidence of cosmic acceleration 20 years ago `https://adsabs.harvard.edu/abs/2018arXiv181102374D`. Many new, more comprehensive and accurate cosmological results will be published in the coming years.

DES-Spain scientists have played and play a leading role in data analysis. In the cosmological findings to date, IFAE researchers have been leaders in determining the distance to galaxies, which is an essential element in interpreting observations made, as well as in the study of correlations between positions. of nearby galaxies and the shape of distant galaxies. ICE-CSIC / IEEC has been involved in dark matter mapping, simulations, and galaxy clustering. The IFT-UAM / CSIC has constructed synthetic catalogs for the study

of systematic errors and covariance matrices. CIEMAT has been one of the institutions responsible for building galaxy catalogs and studying their galaxy catalogs, one of the tests used to obtain cosmological results.

The task of accumulating such a large amount of data is not small. Throughout the mapping, hundreds of scientists were required to operate the instruments for several nights, in turns, with the help of observatory technicians. To organize this effort, DES adopted some of the methods used in particle physics experiments, in which every person working in the experiment somehow collaborates in its operation.

DECam will remain mounted on the Cerro Tololo White Telescope for another 5 or 10 years and will continue to be a very useful instrument for collaborations around the world.

The DES collaboration will now focus on producing new results using the 6 years of data, including new observations on dark energy. Even if an era ends for DES, the next phase of exploration has just begun.

You can follow the current DES at www.darkenergysurvey.org, and also on Facebook www.facebook.com/darkenergysurvey, Twitter www.twitter.com/theDESurvey, and Instagram www.instagram.com/darkenergysurvey.

The Dark Energy Survey is a collaboration of more than 400 scientists from 26 institutions in seven countries. Funds for DES projects have been provided by the U.S.A. Department of Energy Office of Science, U.S.A. National Science Foundation, the Ministry of Science, Innovation, and Universities of Spain, Science and Technology Facilities Council of the United Kingdom, Higher Education Funding Council for England, ETH Zurich for Switzerland, National Center for Supercomputing Applications at the University of Illinois at Urbana- Champaign, Kavli Institute of Cosmological Physics at the University of Chicago, Center for Cosmology and Astroparticle Physics at Ohio State University, Mitchell Institute for Fundamental Physics and Astronomy at Texas A&M University, Fundador de Estudios e Projetos, Fundación Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro, the National Council for Scientific and Technological Development and the Ministry of Science and Technology, Deutsche Forschungsgemeinschaft, and the collaborating institutions listed at www.darkenergysurvey.org/collaboration.

Contact persons: Dr. Enrique Gaztañaga, ICE-CSIC/IEEC, gazta@ice.csic.es ; Dr. Ramon Miquel, Director of IFAE and Research Professor ICREA, ramon.miquel@ifae.es; Dr. Eusebio Sánchez, Scientific Researcher CIEMAT, eusebio.sanchez@ciemat.es; Dr. Juan García-Bellido, Professor of UAM and member of IFT, juan.garciabellido@uam.es.

15.2 The PAZ satellite records the first signs of heavy rainfall

January 22, 2019

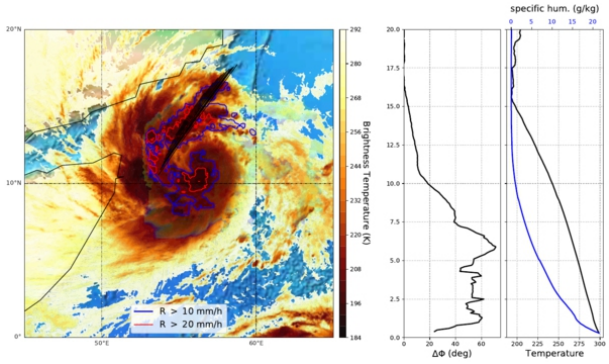

Figure 15.2: A ROHP-PAZ profile crossing the bands of intense rain in a category-3 cyclonic storm Image from the supplementary materials in Cardellach et al., 2019.

- Launched in February 2018, the Spanish satellite incorporates technology designed by CSIC scientists
- Today, public access to the data of the first five months of the mission is given
- This information will serve to deepen key atmospheric parameters in weather forecasting.

A team of researchers from the Institute of Space Sciences of the Higher Council for Scientific Research (CSIC) and the Institute of Space Studies of Catalonia has analyzed the data obtained by the experiment with GPS signals onboard the Spanish satellite of Earth observation PAZ, launched in February 2018, and has confirmed that the recorded signals are sensitive to heavy rainfall. The work and data analyzed by scientists are published in the latest issue of the journal Geophysical Research Letter.

GPS signals are being captured by the satellite with technologies conceived and designed by this group of CSIC scientists in the framework of the ROHP-PAZ experiment, capable of performing radio concealments. The measurements normally measure the thermodynamic properties of the atmosphere (temperature, pressure, and humidity) and, in addition, at different heights. These, for the first time, are being obtained in two polarizations.

Radio concealments are a technique of observing a medium, usually the atmosphere of a planet, using two elements: one that transmits radio or microwave signals (source) and another element that receives them (receiver). The peculiarity of this technique is that, if the transistor and receiver elements are joined in a straight line, it crosses the Earth, that is, the elements are hidden by the Earth. Despite this, the signal is still received because the beam flexes.

“The key is to relate the bending of the signal path with the properties of the atmosphere. On planet Earth, this technique is performed with signals from global satellite navigation systems, such as GPS, ”the CSIC researcher Estel Cardellach, who works at the Institute of Space Sciences.

Navigation systems are the sources, and a receiver onboard a low-orbital satellite (such as the PAZ satellite) contains the receiver. The receiver can measure the bending angle of the signal very accurately, and from this angle vertical profiles of temperature, pressure and humidity are extracted from the atmosphere.

The novelty of the ROHP-PAZ experiment is that it also measures the delay suffered by the horizontally polarized signal with respect to the vertically polarized delay. The hypothesis of the experiment is that this relative delay occurs when the lightning crosses intense rainfall.
"This experiment aims to demonstrate a new concept of measurement, a completely new technique that had never been tested. We now know that the signals are sensitive to heavy precipitation, and we must determine the best use of the data so that the information they contain can be extracted and useful. This will involve the development of investment algorithms or extraction of geophysical information, "says the CSIC researcher.

First results:

The results obtained during the first five months of mission indicate that, indeed, there are detectable effects on the polarimetry of the signals that are due to hydrometeors (raindrops and other ice or water and ice particles). In addition, the more intense the rain, the more intense the polarimetric effect.

The CSIC researcher adds: "The vertical structures detected in our polarimetric signals are consistent with the precipitation structures that are being observed. These facts indicate that the polarimetric signals in ROHP-PAZ respond to intense precipitation, confirming the hypothesis of the experiment.

In the coming months, the researchers hope to be able to close the calibration of the instrument and that all this information can be easily interpreted by the scientific community. For this, the collaboration with teams from NASA's Jet Propulsion Laboratory, the University Corporation for Atmospheric Research and the National Oceanic and Atmospheric Administration is already underway.

Today, public access to the first polarimetric data, corresponding to the first five months of the mission, is given on the project website https://paz.ice.csic.es/. The goal is for thermodynamic data to be distributed in near real-time to global meteorological services. The National Oceanic and Atmospheric Administration will use its antennas and infrastructure to obtain ROHP-PAZ data every time they have contact with the satellite (ideally once every orbit, that is, every hour and a half). "The tests of this operation have already begun and we hope to begin to disseminate the data soon operationally," says Cardellach.

The PAZ satellite with radar technology is a dual mission, with civil and military applications. HISDESAT is the owner, operator

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15.3 The last two GFA units will be sent to the USA for their integration in the DESI instrument

February 4, 2019

The last two Guiding, Focusing and Alignment (GFA) units will be sent to LBNL (Lawrence Berkeley National Laboratory, USA) in the next few days for their integration in DESI (Dark Energy Spectroscopic Instrument) in the framework of the international collaboration.

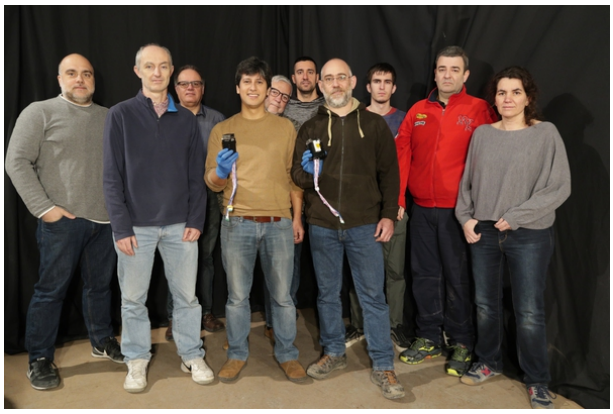

Figure 15.3: Members of IFAE and ICE/IEEC involved in the development of the GFA units of DESI Otger Ballester (IFAE)

The Spanish institutions, Institut de Física d'Altes Energies (IFAE), Institut de Ciències de l'Espai (ICE, CSIC), Institut d'Estudis Espacials de Catalunya (IEEC), CIEMAT and IFT/UAM have developed, built and tested twelve GFA units (ten of them to be integrated in the instrument plus two spares). The GFA units use 2 x 2 k Teledyne-e2v CCD detectors. Our team has developed the electronics, mechanics and cooling systems and their associated software. These units will allow to focus the optical fibres of DESI, align these 5,000 fibres with the objects to be observed and to do the guiding during the exposure time.

DESI will see its first light in the next months.

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15.4 Carbonaceous chondrites provide clues about the delivery of water to Earth

February 14, 2019

A study led by researchers of Institute of Space Sciences (ICE, CSIC) and Institut d'Estudis Espacials de Catalunya (IEEC) discovers how these meteorites retained water and organic material inside them before reaching our planet. Researchers suggest that billions of tons of carbonaceous chondrites reached Earth about 3.800 millions of years ago

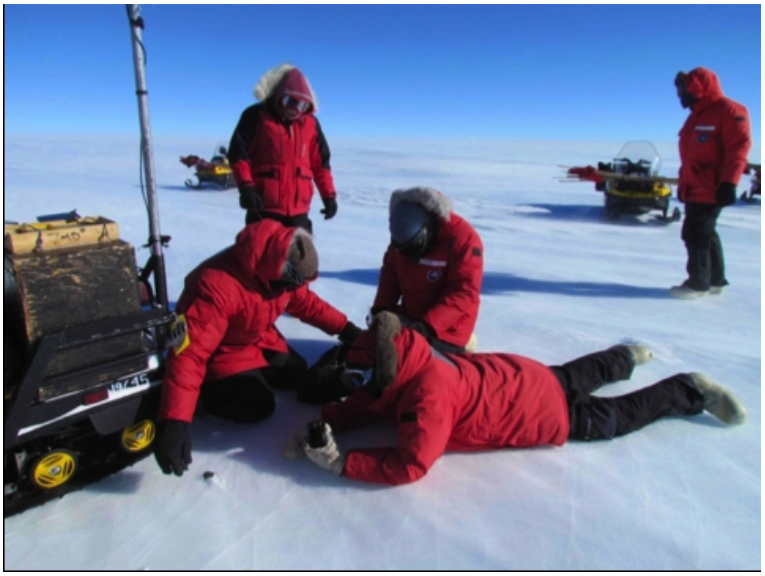

Figure 15.4: Sample collecting of meteorites in the Antarctica Katherine Joy / ANSMET

An international study led by researchers from the Institute of Space Sciences (ICE, CSIC)and the Institut d'Estudis Espacials de Catalunya (IEEC) has discovered that carbonaceous chondrites, a class of meteorites, incorporated hydrated minerals along with organic material from the protoplanetary disk before the formation of planets. Scientists from the study published in the journal Space Science Reviews note that these meteorites played "an important role in the primordial Earth's water enrichment" because they facilitated the transportation of volatile elements that were accumulated on the external regions of the so-called protoplanetary disk from which planets were formed more than 4.500 millions of years ago. Earth was formed in an environment close to the Sun, very much reduced due to the relative lack of oxygen.

Carbonaceous chondrites come from asteroidal bodies that due to their size, generally inferior to hundred kilometres, never melted, and neither suffered internal chemical differentiation as planets did. Thus, the study gives clues about the initial accretion phases of the first bodies that formed the planets. The meteorites analysed in this work belong to the NASA's Antartic collection, whose CSIC's Institute of Space Sciences is the only repository Spanish centre, and the meteorites that fell in Murchison (Australia) in 1969 and in Renazzo (Italy) in 1824. Representative samples of the two more-hydrated types of carbonaceous chondrites (CM and CR groups) have been studied.

"Chondrites constitute a fossil legacy of the creation of the planetesimals, which pro-

vide information about the accretion of the first building blocks of planets, and also about everything that happened inside them shortly after their formation. In this study, we want to go a step further to identify processes of water incorporation befallen in the same protoplanetary disk", explains CSIC researcher Josep M. Trigo-Rodríguez, who works at the Institute of Space Sciences and has led the study.

ICE/IEEC researcher adds: "There is a great debate about the origin of water in Earth and our study proves that carbonaceous chondrites were able to transport water in a very efficient way in their matrices. That water seems to come from two types of objects formed at different distances from the Sun: hydrated asteroids and comets. Obviously, in order to know the origin of water in Earth, we must study not only the comets but also the carbonaceous chondrites that come from an asteroid population called transitional. These bodies were far more numerous 4.000 millions of years ago, but suffered a gravitational destabilisation during Jupiter and Saturn's migration to its current location. Those that did not end being swallowed by Jupiter and Saturn were rejected towards the terrestrial planets and to other regions of the Solar System, transporting water and organic material inside them", explains the researcher.

The study also points at the direct implications for the origin of water in Earth. "Our calculations indicate that, coinciding with the so-called 'Heavy Bombardment' produced by the gravitational destabilisation of the main asteroid belt, billions of tons of carbonaceous chondrites reached Earth about 3.800 millions of years ago. And they did it transporting in their fine matrices water and other volatile elements in form of hydrated minerals", says Trigo.

In this study have participated Safoura Tanbakouei and Victoria Cabedo from the Institute of Space Sciences; Albert Rimola from the Universitat Autònoma de Barcelona; and Martin Lee from the University of Glasgow (Scotland).

Aims for future missions:

Currently, there are two ongoing missions for sample return from primitive asteroids: NASA's OSIRIS-Rex and JAXA's (Japan Aerospace Exploration Agency) Hayabusa 2. The results from the carbonaceous chondrites' analysis at a micro- and nanoscale that are published in this new study reveal the importance of the sample-return missions, that can bring to Earth rocks less altered by collisions than the meteorites that land on the terrestrial surface.

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15.5 Primordial comet fragment discovered inside meteorite gives clues to the origin of the Solar System

April 15, 2019

Using the only international repository of NASA's Antarctic meteorites based in Spain, at ICE, a study co-led by IEEC– CSIC has revealed a comet fragment inside the carbonaceous chondrite meteorite LaPaz 02342.

An international team including researchers from the Institute of Space Studies of Catalonia (IEEC) at the Institute of Space Sciences (ICE, CSIC) has discovered a pristine comet fragment inside a meteorite. This finding demonstrates that the class of meteorites known as carbonaceous chondrites contains clues to the composition of more fragile objects that formed in regions distant from the Sun, more than 4,560 million years ago. The results are published in the journal Nature Astronomy.

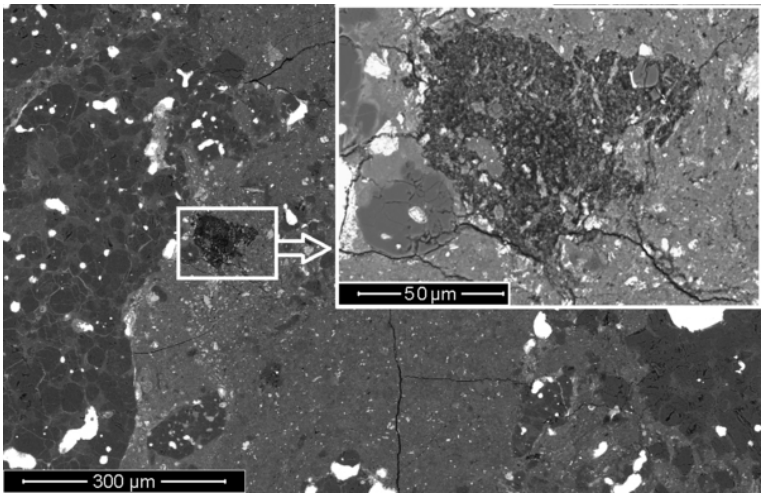

Figure 15.5: Section of the carbonaceous chondrite LaPaz 02342 and extension of the cometary dust speck. Credit: IEEC-CSIC/Carnegie Institution for Science.

After a three-year study of the carbonaceous chondrite LaPaz 02342, from NASA's Antarctic collection, researchers have come to the conclusion that the comet fragment, of about one hundred microns, is composed of an unusual mixture of organic materials, amorphous and crystalline silicates, sodium sulphates, sulphides, and presolar grains; the latter synthesised in stars that enriched the original materials of our Solar System. Among other instruments, a secondary ion mass spectrometer (nano-SIMS) of the Carnegie Institution for Science (USA) has been used for its analysis, which allows studying at a nanometric scale the composition of the meteorite at an isotopic and elemental level.

"This fragment, technically known as xenolith, has unusual characteristics that we think were produced from the incorporation of primitive materials embedded in ice. Many objects in the Solar System have a very different composition than the meteorites available in terrestrial collections. Carbonaceous chondrites, such as LaPaz 02342, constitute a fossil legacy of the creation of the planetesimals in their interior and are capable of preserving unique samples of other objects much richer in organic and volatile matter, known as comets", explains Trigo Rodriguez.

As the researcher points out: "The asteroid progenitor of this carbonaceous chondrite underwent aqueous alteration, but fortunately, it was neither extensive nor homogeneous. This led to the preservation of the unique properties of this cometary dust speck, among which the richness in tiny mineral grains formed in stars of the same environment in which the Sun was born." The study concludes that this tiny fragment incorporated not only ice but also materials from the interstellar medium. The fragment was also irradiated by high-energy cosmic rays, a process in which tiny glasses known as GEMS (Glass with Embedded Metal and Sulfides) were created.

The most primitive meteorites:

Carbonaceous chondrites come from transitional bodies, a category falling between asteroids and comets. Given their sizes typically smaller than a few hundred kilometres, such bodies never melted or suffered internal chemical differentiation as occurred to the planets. The materials that make up these objects are usually fragile and do not usually survive the transit of tens of millions of years that transport them from their parent bodies to the Earth orbit. In case they do, they fragment and volatilise when entering into the atmosphere at hypersonic velocities. Precisely because of this reason, ultracarbonaceous materials such as those discovered are extremely rare and have only been identified as micrometeorites.

The search for primordial materials among the most primitive meteorites can be carried out at ICE, given that it is the only international repository of NASA's Antarctic meteorites in Spain. The samples studied by the IEEC–CSIC scientific team come from NASA's Johnson Space Center. Hence, researchers have access to unique specimens, being able to select those that have not undergone thermal metamorphism or extreme aqueous alteration.

This discovery is part of the National Astronomy and Astrophysics Plan project (AYA-2015-67175-P) for the study of primitive materials preserved in meteorites led by Josep M. Trigo-Rodriguez. Carles E. Moyano-Cambero and Safoura Tanbakouei, from IEEC at ICE (CSIC), have also participated. The international cooperation has been led by Larry Nittler from the Carnegie Institution for Science, in collaboration with his colleagues Conel Alexander and Jemma Davidson, as well as Rhonda Stroud and Bradley De Gregorio of the U.S. Naval Research Laboratory.

More information.
This research is presented in a paper entitled "A cometary building block in a primitive asteroidal meteorite", by Nittler L.R. et al., to appear in the journal Nature Astronomy on 15 April 2019.

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15.6 CARMENES finds two temperate Earth-mass planets around a nearby small star

June 18, 2019

Researchers from the Institute of Space Sciences (ICE, CSIC) and from Institute of Space Studies of Catalonia (IEEC) have participated in an international study carried out by the CARMENES consortium, which has discovered two small, terrestrial planets around Teegarden's Star. The planets have masses similar to Earth and their temperatures could be mild enough to sustain liquid water on their surfaces. Observations were carried out with the CARMENES instrument in Calar Alto (Spain), as well as several other smaller complementary facilities, including IEEC's Telescopi Joan Oró, at the Montsec Astronomical Observatory. The scientific paper is led by researchers at the University of Göttingen and appears in Astronomy & Astrophysics.

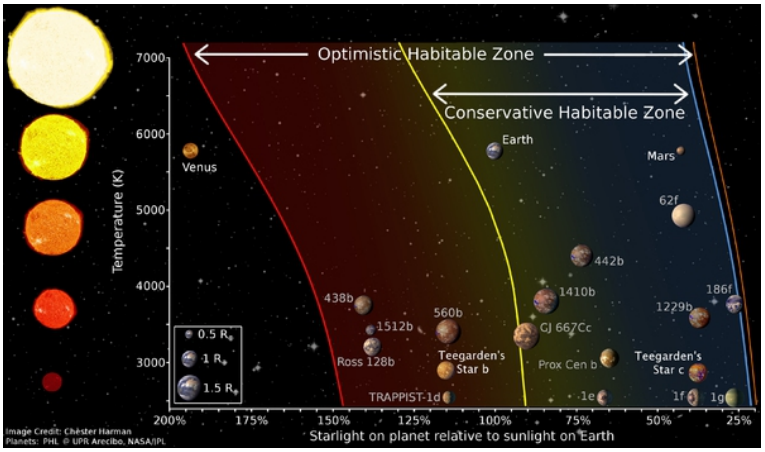

Figure 15.6: Planets in the habitable zone around a star Image: Chester Harman / Planets: PHL @ UPR Arecibo, NASA/JPL

At a distance of only 12.5 light years, Teegarden's Star is the 24th nearest star system to ours, and one of the smallest red dwarf stars known. Despite its proximity and due to its faintness, Teegarden's Star was only identified in 2003.

"We have been observing this star with the CARMENES instrument since the beginning of the survey three years ago to measure its motion very precisely" explains Dr. Mathias Zechmeister, a postdoctoral researcher at the University of Göttingen (Germany), and lead author of the publication.

The method used to detect the planets was the so-called Doppler technique. A planet orbiting a star causes a small back-and-forth reflex motion. This motion induces a very subtle Doppler effect on the star light, which is then measured down to a precision of 1 meter per second with CARMENES, the equivalent of walking speed, or 3.6 km/h. Small planets produce a small signal, but their signals are easier to detect on small red dwarfs like Teegarden's Star rather than on a star like the Sun because the reflex motion is larger

and it repeats more often.

"CARMENES is the first high-precision spectrometer in operation specifically designed to find planets using this 'red dwarf advantage'," adds Mathias Zechmeister. Teegarden's temperature is only 2600^{o}C (compared to the 5500^{o}C of the Sun), it is 1500 times fainter and ten times less massive than our Sun. As a result, it radiates most of its energy in the red and infrared which made it an ideal target for the CARMENES survey.

The Doppler measurements of Teegarden's Star showed the presence of at least two signals, now reported as the two new exoplanets, Teegarden's Star b and c. Obtaining a robust detection with a new instrument required the collection of over 200 measurements. Based on the measured motion, the researchers can deduce that Teegarden's Star b has a mass similar to that of the Earth, it orbits the star every 4.9 days at about 2,5% the Earth-Sun distance. Teegarden's Star c is also similar to the Earth in terms of mass, completes its orbit in 11.4 days and is located at 4,5% the Earth-Sun distance. Since Teegarden's Star radiates much less energy than our Sun, the temperatures on these planets should be mild and they could, in principle, hold liquid water on their surfaces, especially the outer one, Teegarden's Star c. This kind of planets is the primary target for future searches for life beyond our Solar System.

A major milestone of the CARMENES project:

As opposed to previous CARMENES discoveries that combined measurements from several instruments, such as Barnard's star b, all high-precision Doppler measurements and follow-up observations used for this finding have been obtained by the CARMENES consortium. Several groups within the consortium used smaller telescopes to monitor changes in the brightness of the star to rule out alternative explanations such as star spots or other surface features. The follow-up activities included intensive photometric campaigns at the 1.23-m Calar Alto Telescope/CSIC, the Sierra Nevada Observatory/IAA-CSIC and the Telescopi Joan Oró-Montsec/IEEC, among others.

"This discovery is a great success for the CARMENES project, which was specifically designed to search for planets around the least massive stars", says Dr. Ignasi Ribas, a researcher from IEEC at ICE/CSIC, and project scientist of CARMENES. The new planets are number ten and eleven in the CARMENES exoplanet discovery tally, and the search continues.

"Both planets may be part of a larger system," says Prof. Stefan Dreizler from University of Goettingen and co-author of the study. "Very low-mass stars seem to have densely populated planetary systems" More data may reveal an even richer system.

"The unique feature of our instrument, which allows it to observe simultaneously in the visible and near infrared, is fundamental to confirm the nature of the signals detected with both channels as due to the presence of planets in orbit, since in this case, the amplitude of the signal does not depend on the channel with which it is measured, contrary to what happens when the signal is due to the star's intrinsic variability," points

out Dr. Pedro Amado from IAA/CSIC, and deputy principal investigator of CARMENES.

More information:
The CARMENES (Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs) instrument is a high-resolution optical and near-infrared spectrograph built in collaboration by 11 Spanish and German research institutions, and it is operated by the Calar Alto observatory (Spain). CARMENES has been working non-stop since 2016.

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15.7 Regular release of RHOP-PAZ dual-polarization data starts today

July 17, 2019

Figure 15.7: Snapshot of PAZ access point at UCAR's CDAAC server

The first dual-polarized GNSS radio occultation data, acquired by ICE-CSIC/IEEC experiment aboard PAZ (RHOP-PAZ), have been released by UCAR. The initial batch of files covers the period from May 10, 2018 to April 29, 2019, and it will be regularly updated from this moment on. The post-processing products will be continuously provided with several weeks latency. The data access point is at:
https://cdaac-www.cosmic.ucar.edu/cdaac/products.html

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15.8 Mysteriously in-sync pulsar challenges existing theories

September 16, 2019

Researchers from the Institute of Space Studies of Catalonia (IEEC) at the Institute of Space Sciences (ICE, CSIC) have contributed to a research study that, for the first time, detected synchronised pulses of optical and X-ray radiation from a mysterious pulsar. The observations indicate that a new physical mechanism might be needed to explain the behaviour of fast-spinning sources like this one, known as transitional millisecond pulsars.

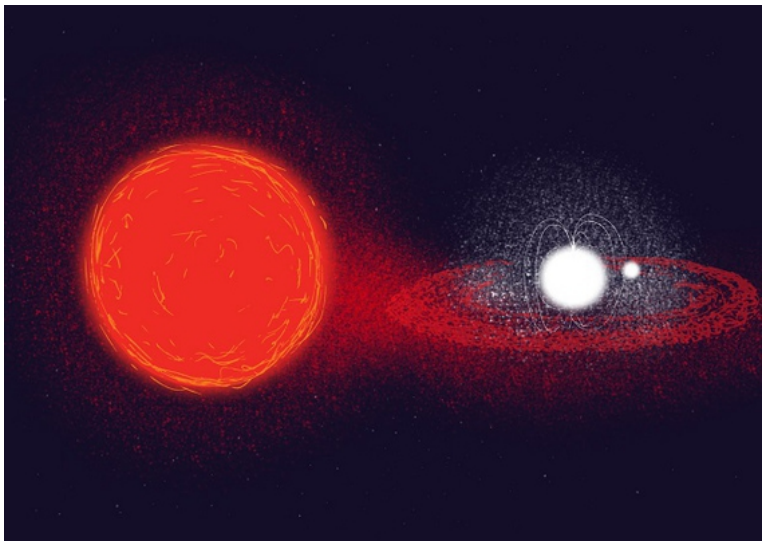

Figure 15.8: Transitional millisecond pulsar PSR J1023+0038 ESA

The discovery was made as part of a two-day observation campaign spearheaded in 2017 by ESA's XMM-Newton X-ray observatory and other telescopes. The group of IEEC researchers at ICE, CSIC — Francesco Coti Zelati, Nanda Rea, Santiago Serrano, and Diego Torres — have taken part in both the X-ray and optical observations, using, among others, the Montsec Observatory (Observatori Astronòmic del Montsec, OAdM) managed by IEEC. The combination of various space- and ground-based facilities[1] allowed the international team of astronomers to measure with very high temporal resolution the two types of radiation coming from the ultrafast rotating pulsar.

The pulsar[2] analysed in this study, known as PSR J1023+0038, spins around its axis

[1]The study combines X-ray observations from ESA's XMM-Newton and NASA's NuSTAR and NICER X-ray observatories with ultraviolet observations from NASA's Swift, optical observations from INAF's optical Galileo National Telescope (TNG), equipped with the fast photometer SiFAP, and the Nordic Optical Telescope (NOT), both located at Roque de los Muchachos Observatory, in La Palma, Canary Islands, Spain, as well as from the Telescopi Joan Oró (TJO), located at the Montsec Observatory in the Catalan pre-Pyrenees, Spain, and infrared observations from the Gran Telescopio Canarias (GTC), also on the island of La Palma.

[2]Pulsars are highly magnetised, fast spinning neutron stars – the relics of massive stars. They are very dense objects, comprising up to two times the mass of the Sun within a radius of only ten km

within a few thousandths of a second. Such pulsars are classed as millisecond pulsars, some of which are also sucking in matter from a companion star – as is the case of this pulsar.

Earlier studies had shown that this pulsar belongs to the rare category of so-called 'transitional millisecond pulsars' that periodically switch between two different modes of emissions – in X-rays and radio waves.

According to the leading model explaining this behaviour, the accretion of matter from the companion star gives rise to the pulsed X-ray emissions, while the radio signal is thought to result from the rotation of the pulsar's magnetic field.

Further observations of PSR J1023+0038, however, revealed that an entirely different explanation might be needed to understand this class of sources.

"PSR J1023+0038 is the very first milisecond pulsar discovered with pulsations also in the optical band," said Alessandro Papitto from INAF in Rome, Italy, lead author of the new study.

The latest data show that the optical pulses in PSR J1023+0038 appear and disappear at exactly the same time as the X-ray ones.

Conventional models could not explain the synchronised pulses so the team had to identify a new scenario that could explain the data. IEEC researcher Diego Torres was part of the group that put forward this new model to explain the detection, while also highlighting the existence of a small lag between the two emissions, yet to be further confirmed observationally.

"Until now, we thought that the pulsed X-ray emissions originated in a different process than the optical radiation. We also expected these processes to take place one after the other, but this is not the case for PSR J1023+0038. The synchronised pulses are an indication that they have the same origin" says Diego Torres.

The new model states that the pulsar might be emitting a strong electromagnetic wind, which then interacts with the accretion disc around the system. As the pulsar wind hits matter in the accretion disc, it creates a massive shock, which accelerates electrons in the wind to extremely high speeds. The electrons then interact with the wind's magnetic field, producing powerful beams of synchrotron radiation that can be observed in the optical and X-ray bands at the same time. All of this would happen at a very close distance from the pulsar, giving rise to the concept of mini pulsar wind nebula.

"The traditional pulsar J1023+0038 is one of the most interesting sources we know. Its multi-frequency variability is incredibly rich, and allows us to study the relationship between the magnetic field and matter in extreme conditions", concludes Torres as he is looking forward to further observations with future technologies.

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15.9 CSIC researchers participate in the largest scientific expedition to the Arctic

September 23, 2019

Figure 15.9: The German icebreaker Polarstern, which transports the MOSAIC expedition Alfred Wegener Institute

- The MOSAIC mission, aboard the Polarstern icebreaker, will be stranded on the ice bench for a year to measure environmental changes due to climate change
- CSIC researchers will study the interaction of marine life in cloud formation and the use of satellite technology to measure the condition and thickness of ice
- The expedition is formed by an international consortium with the CSIC as a Spanish partner funded by the State Research Agency

Three teams of researchers from the Higher Council for Scientific Research (CSIC) participate in the largest scientific expedition to the Arctic in history. This is the MOSAIC project, which, onboard the German research icebreaker Polarstern, departed from Tromso (Norway) on Friday to spend a year trapped in drifting ice across the Arctic Ocean. The objective of the mission is to study the Arctic as the epicenter of global warming to obtain data to better understand global climate change. The project brings together 600 researchers from 19 countries who will work on a rotating basis, and includes three Spanish research teams, all from the CSIC, from the Institute of Marine Sciences

and the Institute of Space Sciences / Institute of Space Studies of Catalonia, and funded by the State Research Agency.

The MOSAIC expedition plan foresees that the Polarstern icebreaker, from the Alfred Wegener Institute (Germany), will sail northeast towards the Laptev Sea, in central Siberia, and enter the ice bench, at a location selected from of satellite and radar data, to be deliberately trapped in the ice. Once fixed, the icebreaker will travel with the ice along a route known as a transpolar drift to the north pole, cross it and then head south to flow into the Fram Strait, between Greenland and the Svalbard archipelago (Norway), between 12 and 14 months later.

In this way, the Polarstern will become an itinerant research center, the so-called MOSAIC, or Multidisciplinary drifting Observatory for the Study of Arctic Climate (Drift multidisciplinary observatory to study the Arctic climate). The expedition will have a team of 60 investigators experts in Arctic research, plus about 40 crew members (in shifts of about two months), who will operate their instruments onboard and on the ice. There the scientists will study the atmosphere, the sea and the ice, and how they interact with each other, in order to better understand how global warming will affect the Arctic region.

From the Institute of Marine Sciences, CSIC researcher Manuel Dall'Osto will travel aboard the Polarstern between July and September 2020 to make atmospheric measurements and study the impact of marine life on cloud formation. "Clouds are key to regulate the temperature of the planet. Without clouds, we would have a much warmer Earth. But we don't understand well enough how they are formed and destroyed, and that is limiting us a lot in the projections of climate and climate change, "he adds. "With our campaign, we want to know what synergy is established between the matter of biological origin and the clouds, what type of plankton favors the formation of clouds and in which regions of the ocean this relationship is more important," explains Dall'Osto.

Also from the Institute of Marine Sciences, another team of researchers will study the mass and thickness of sea ice using satellite measurements. Scientists will deploy a new microwave radiometer, mounted on a sled, which will allow you to measure the thickness of the ice throughout the year. The radiometer operates on the 1.4GHz frequency and has been designed and built by the Spanish company Balamis. "The Arctic is one of the most remote regions of the planet, and of more difficult access, so to continuously monitor the state of the ice it is essential to resort to information via satellite," explains CSIC researcher Carolina Gabarro, director of the study. "Our radiometer will improve the models of radiative transfer of sea ice and snow to achieve more reliable estimates of ice thickness from satellites," he adds.

The information provided by these satellites on sea ice is crucial to understand the changes facing the Arctic under the threat of climate change and, in particular, to study the evolution of sea ice mass and Arctic balance," says Gabarro. "All these measures will improve the mathematical models, and therefore the geophysical information offered by the SMOS (of the European Space Agency) and SMAP (NASA) satellites that measure the thickness of sea ice," the researcher details.

The third Spanish team working on the MOSAIC expedition belongs to the Institute of Space Sciences (ICE, CSIC) and the Institute for Space Studies of Catalonia (IEEC) and will study the interaction between sea ice and navigation signals transmitted from satellite (like the GPS). "These signals, after being reflected in the ice, can be detected and analyzed to extract information from sea ice: its thickness, roughness, amount of salt, presence of surface water, etc.", explains CSIC researcher Estel Cardellach, from ICE / IEEC.

The ICE / IEEC study will be carried out through two experiments: one installed on the ice bench and another onboard a research plane that will fly over the area and collect large amounts of data, which will be added to the data obtained by other groups of MOSAIC research. "If studies confirm that this measurement technique using navigation signals provides high accuracy, it could be applied from low-cost satellites to monitor the poles continuously," says Cardellach.

The Arctic, sentry of climate change
Temperatures rise throughout the planet, mainly due to human activity that emits greenhouse gases into the atmosphere, but in the Arctic, temperatures rise twice as fast as in other regions, and their effects are more evident than in any other place. For example, ice shrinks and becomes thinner as the Arctic warms.

The Arctic is one of the most remote areas of the planet, only accessible for a few months in summer when the ice melts. As the MOSAIC expedition will travel adrift for a year, it will allow data to be obtained throughout the annual ice cycle, from its growth until it melts.

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15.10 PAZ Radio Occultation profiles being operationally assimilated into a numerical weather prediction model

September 24, 2019

Helsinør, Denmark, September 24, 2019.

Researchers of the U.S. Naval Research Laboratory (NRL) announced that data acquired by the Radio Occultation and Heavy Precipitation experiment aboard PAZ (ROHP-PAZ) are being assimilated operationally into the US Navy Global Environmental Model (NAVGEM) which is run operationally by Fleet Numerical Meteorology and Oceanography Center (FNMOC) since 15t August 2019. The announcement was made at the 7th International Radio Occultation Working Group (IROWG-7) meeting and EUMETSAT ROM-SAF User Workshop held in Helsingør, Denmark. NRL provided the capability to

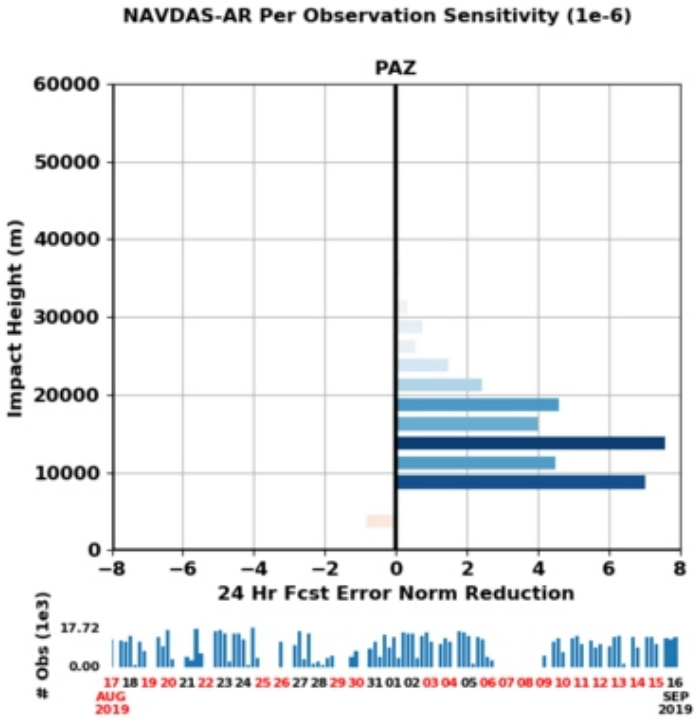

Figure 15.10: Reduction of the weather forecast error due to PAZ radio occultation observations. NRL and FNMOC

assimilate PAZ ROHP-PAZ to FNMOC, and continues to contribute to the development and maintenance of the NAVGEM system for weather forecasts and related services. The present quality levels of the PAZ data have shown consistent positive impact to weather analysis and forecasts similar to the other radio occultation missions. This effort is extremely useful to the RO community, and a significant step towards the assimilation of PAZ data into other operational weather prediction models.

The ROHP-PAZ experiment is led by the Earth Observation group at the Institute of Space Sciences (ICE-CSIC) and Institute of Space Studies of Catalonia (IEEC). Signals transmitted by the Global Positioning System (GPS) are acquired at the PAZ satellite when these transmitters are setting behind the limb of the Earth ('occulting'). These signals contain information about the vertical structure of thermodynamic variables of the atmosphere, improving the weather forecast when injected into the prediction models. PAZ radio occultation data are downloaded to the ground and processed to intermediate products in near-real time by the USA National Oceanic and Atmospheric Administration (NOAA) and the University Corporation of Atmospheric Research (UCAR), through agreements with the ICE-CSIC/IEEC. These products, suitable for assimilation into the numerical weather prediction models, are currently being disseminated in near real time to NOAA related centers, while waiting for prompt dissemination to weather services worldwide through the Global Telecommunication System of the World Meteorological Organization (WMO).

ROHP-PAZ is an opportunistic experiment aboard PAZ low Earth orbiter, a satellite owned, operated and exploited by HISDESAT. The experiment is funded by the Spanish Ministry of Science, Innovation and Universities.

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15.11 CARMENES: Giant exoplanet around a small star challenges our understanding of how planets form

September 26, 2019

Figure 15.11: Infographic of GJ3512 orbit comparison Credit: Guillem Anglada-Escude - IEEC, using SpaceEngine.org. Distribution license: Creative Commons Attribution 4.0 International (CC BY 4.0).

- A study from the CARMENES consortium led by IEEC researchers at ICE (CSIC) reports the discovery of an anomalous planetary system around the nearby red dwarf GJ 3512, located at approximately 30 light-years from us. Although the star is only about a tenth of the mass of the Sun, it possesses at least one gas giant planet.
- This planet probably formed from an unstable disc around the young star which broke up into clumps. This contrasts with how the majority of massive planets are believed to form, where a planet grows slowly as gas falls onto a solid core.
- The signal of the planet is clearly detected with both the visible and infrared arms of the CARMENES spectrograph at the Calar Alto Observatory . This makes it

the first exoplanet unambiguously discovered by a new-generation infrared high-resolution spectrometer.

- For this discovery, the CARMENES consortium used, among others, IEEC's 80-cm diameter Joan Oró Telescope (TJO) at the Montsec Observatory and the facilities at Observatorio de Sierra Nevada (IAA, CSIC).
- The result will be published in the forthcoming issue of the journal Science.

Astronomers from the CARMENES consortium, led by Juan Carlos Morales, a researcher from the Institute of Space Studies of Catalonia (IEEC) at the Institute of Space Sciences (ICE, CSIC) have discovered one, possibly even two, gas giant planets orbiting the nearby red dwarf star GJ 3512.

To discover the planets, the astronomers used the Doppler technique, which monitors the back-and-forth motion of a star when it is orbited by one or more planets. The star however almost did not make it into the list of observational targets.

"CARMENES was built to find planets around the smallest stars, but we also wanted them as bright as possible. Initially, this star was not included in our observation list because it was too faint," declares Ignasi Ribas, CARMENES project scientist and Director of IEEC. "We then realised we didn't have enough small stars in the sample and we added a few, at the very last minute. We were lucky to do so because otherwise we would have never made this discovery".

The 140 observations clearly reveal a motion of the star caused by a massive companion in both the optical and infrared arms of the CARMENES spectrograph. The infrared arm of CARMENES was the core contribution of the Spanish institutes to the consortium and it was built at CSIC's Instituto de Astrofísica de Andalucía. The instrument is in operation since 2016 at the 3.5 meters telescope in the Calar Alto Observatory in Almeria (Spain).

"As their name indicates, red dwarfs emit most of their light in the red and near infrared parts of the spectrum. CARMENES was designed to make optimal use of all the light wavelengths where the stars are brighter," explains Ansgar Reiners, from the Institute for Astrophysics Göttingen, in Germany. "Despite the fact that optical high-resolution and stabilised spectrographs have existed for a while, for example HARPS, near-infrared ones represent a new technology."

With this discovery, CARMENES achieves the first detection of an exoplanet solely using a new-generation near-infrared precision instrument, highlighting again the leading role played by European researchers in the field of exoplanets. An earlier detection of an exoplanet using an infrared spectrometer required the use of several other facilities to confirm it[3]

[3]Technically speaking, the first solid exoplanet detection reported using a high resolution infrared spectrometer was done with CSHELL at IRTF, and corresponds to a massive object at the limit between a planet and a brown dwarf (13 Mjup) in orbit around CI Tau . CARMENES is a new-generation

After a few initial observations, this target caught the attention of scientists and triggered further monitoring. "The star was showing a rather strange behaviour very early on. Its velocity was changing very rapidly, and consistently in both wavelength channels of the instrument, indicating the presence of a massive companion, an anomalous feature for a red dwarf," explains Juan Carlos Morales.

GJ 3512 is almost identical to Proxima Centauri and only a bit more massive than Teegarden's star and TRAPPIST-1 , which all host terrestrial planets in temperate orbits, but no gas giants. "It is becoming the norm to expect small planets around these small stars, so we initially thought this large motion had to be caused by another star in a very long orbital period. We kept observing it, but on low priority. To our surprise, the motion started to repeat again in the next season, indicating that it was actually produced by a planet. At that point, GJ 3512 finally made it to the top priority list," explains Dr. Morales.

"IEEC's 80-cm diameter Joan Oro Telescope at the Montsec Observatory played a significant role in the discovery, allowing the astronomers to derive the rotational period of the system at 87 days, an important step to confirm that the signal is a planet and not stellar activity, as well as to estimate the age of the system", declared Enrique Herrero, IEEC researcher.

Planet formation models should be able to explain how planetary systems come into existence around stars like our Sun, but also around smaller stars. Until now, the so-called "core accretion model" for planet formation was considered sufficient to explain Jupiter and Saturn in our Solar System, and many other gas giant planets discovered around other stars.

The "core-accretion" model assumes that planets form in two phases: at first, rocky cores, the size of a few Earth masses, form a nucleus within the protoplanetary disk and then, when a critical mass is reached, they start to accumulate and retain large amounts of gas until they reach the mass of Jupiter or more.

Low-mass stars should have proportionately low-mass disks, so the amount of available material in the disk to form planets is also significantly reduced. The presence of a gas giant around a low-mass star indicates that either the original disk was anomalously massive[4] or that the core-accretion scenario does not apply in this case. Moreover, this planet is on an eccentric orbit, which is the smoking gun of a past event indicating the presence of another massive planet that was ejected from the system in a chaotic interaction with the current planet, adding a wandering planet in the galactic void.

Researchers from IEEC, the Max Planck Institute for Astronomy (MPIA) and other

instrument specifically built for exoplanet searches. Since CARMENES started operations, a number of similar instruments came on-line at top world observatories, such as the Subaru Telescope and the Canada-France-Hawaii Telescope, both in Mauna Kea, Hawaii.

[4]The existence of such anomalously massive disks is currently not confirmed by observations of star forming regions

CARMENES institutes established a collaboration with the planet formation groups at Lund Observatory in Sweden and Bern University in Switzerland , all of them world leaders in planet formation theory, to study plausible formation scenarios for this system.

"After running multiple simulations and long discussions among the different groups to try to explain the system, we concluded that our most up-to-date models could never allow the formation of even one massive planet, let alone two," explains Alexander Mustill, a Senior Research Fellow at Lund Observatory.

But there is a possible alternative planet formation scenario that could save the day. The "disk-instability model" advocates that some or maybe all gas giant planets can directly form from the gravitational self-accumulation of gas and dust instead of requiring a "seed" core. Although this scenario is plausible, it has been mostly ignored so far because it fails to explain other trends observed for the population of gas giant planets. This new CARMENES discovery is bound to change this.

"I find it fascinating how a single anomalous observation has the potential to produce a paradigm shift in our thinking, in something as essential as the formation of planets and, therefore, in the big picture of how our own Solar System came into existence," declares Juan Carlos Morales.

The CARMENES consortium keeps monitoring the star in order to confirm the existence of a second, possibly a Neptune-like object, in a longer orbital period. Besides, the scientists have not discarded the presence of temperate terrestrial planets orbiting GJ 3512. More data will tell if it turns out to be a small scale Solar System.

Observatories and Instruments:

The CARMENES (Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs) instrument is a high-resolution optical and near infrared spectrograph built in collaboration by various Spanish and German research institutions, and it is operated by the Calar Alto observatory (Spain) .

More information:

This research is presented in a paper entitled "A giant exoplanet orbiting a very-low-mass star challenges planet formation models", by J. C. Morales et al., to appear in the journal Science on 27 September 2019.

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15.12 Twin baby stars grow in complex network of gas and dust

October 03, 2019

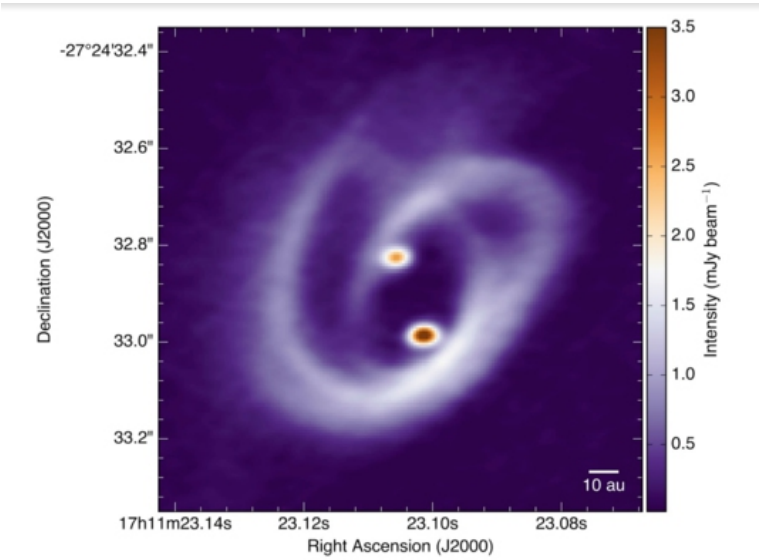

Figure 15.12: Pretzel-type filaments Credit: Felipe O. Alves (MPE)

- For the first time, high-resolution images obtained with the Atacama Large Millimetre/submillimetre Array (ALMA) show a young stellar binary system in which a complex network of accretion filaments is nurturing two proto-stars.
- Each star has a circumstellar disk of its own and together, the stars and their disks, have another, larger, circumbinary disk.
- The team was led by Felipe Alves, currently at the Max Planck Institute for Extraterrestrial Physics, who did his doctoral studies at the Institute of Space Sciences (CSIC), under the coordination of IEEC member Dr. Josep Miquel Girart, who is also the third author of the study.
- The results appear in the journal Science.

Most stars in the Universe come in the form of pairs – binaries – or even multiple star systems. Now, the formation of such a binary star system has been observed for the first time with high-resolution ALMA (Atacama Large Millimetre/submillimetre Array) images.

An international team of astronomers targeted the system [BHB2007] 11, the youngest member of a small cluster of young stellar objects in the Barnard 59 dark nebula, which is part of the cloud of dust and gas called the Pipe nebula. While previous observations showed a rotating and infalling envelope surrounding a circumbinary disk, the new observations now also reveal its inner structure.

"We see two compact sources, that we interpret as circumstellar disks around the two young stars," explains Felipe Alves from the Max Planck Institute for Extraterrestrial

Physics (MPE). The stars grow bigger by pulling matter from these disks. "The size of each of these disks is similar to the asteroid belt in our Solar System and their separation is slightly smaller than our Solar System as a whole." In addition, both protostars and their circumstellar disks are surrounded by a bigger disk, called a circumbinary disk, with a total mass of about 80 Jupiter masses, which shows a complex network of dust structures distributed in spiral shapes, resembling a pretzel.

Astronomers have observed an accretion process in two stages. In the first stage, mass is transferred from the big, circumbinary disk to the circumstellar disks. In the second stage, mass is transferred from the circumstellar disks to the stars. "Thanks to the power of ALMA, we have managed to peer deeper into the complex system of young binary stars and gain a better understanding of how such systems form, as well as find out that the formation of rocky planets in such environments may be possible. Using this knowledge, we can now study more similar systems to further describe the conditions that allow for multiple star systems to form," declared Dr. Josep Miquel Girart, a researcher from the Institute of Space Studies of Catalonia (IEEC) at the Institute of Space Sciences (ICE, CSIC) and third author of the study.
Observatories and Instruments:

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of ESO, the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI). ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

More information:

This research is presented in a paper entitled "Gas flow and accretion via spiral streamers and circumstellar disks in a young binary protostar", by F. O. Alves, P. Caselli, J. M. Girart et al., to appear in the journal Science on 4 October 2019.

Contact persons: Dr. Felipe Alves, Max Planck Institute for Extraterrestrial Physics, falves@mpe.mpg.de; Dr. Josep Miquel Girart, ICE-CSIC/IEEC, girart@ice.csic.es.

15.13 DESI Opens Its 5000 Eyes to Capture the Colors of the Cosmos

October 28, 2019

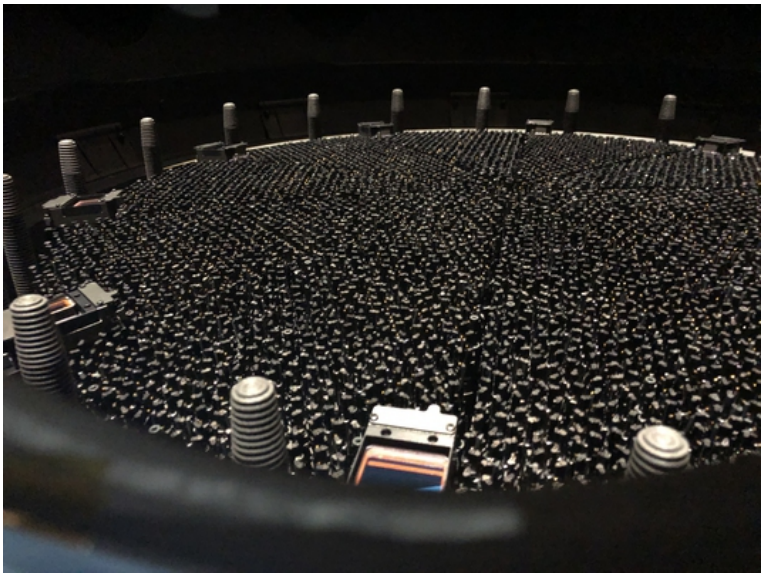

Figure 15.13: DESI full focal plane view: DESI Collaboration

DESI Opens Its 5000 Eyes to Capture the Colors of the Cosmos

- The Dark Energy Spectroscopic Instrument (DESI), a new instrument designed to accurately map the universe, begins its final testing stage.
- Researchers from the Institut de Física d'Altes Energies (IFAE), the Institute of Space Science (ICE, CSIC), the Institut d'Estudis Espacials de Catalunya (IEEC), the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) and the Instituto de Física Teórica (IFT, UAM-CSIC) participate in the project.

A new instrument installed in a telescope in Arizona (USA) that will observe a record number of galaxies and quasars, made its first light observation by pointing its 5000 fiber-optic "eyes" towards the cosmos this past night of Monday, 28 October, to test its unique view of the universe.

The Dark Energy Spectroscopic Instrument, known as DESI, which installation is about to be completed. The instrument is designed to explore the mystery of dark energy, which makes up approximately 68% of the universe and is responsible for its accelerated expansion. To this end, DESI will observe for 5 years a third of the sky with the aim of mapping the distance between the Earth and 35 million galaxies, plus another 2.4 million quasars. The instrument will start scientific observations in early 2020.

The most detailed three-dimensional map of the Universe:

As if it was a powerful time machine, DESI will investigate the universe's childhood and early evolution (about 11 billion years ago) to create the most detailed three-dimensional

map of the Universe to date.

DESI will also provide very accurate measurements of the universe's rate of expansion and how it has varied over time. Gravity slowed this expansion in the early universe but, ever since, the action of dark energy has been responsible for accelerating its expansion.

"After a decade in planning and R&D, installation and assembly, we are delighted that DESI can soon begin its quest to unravel the mystery of dark energy," says DESI Director Michael Levi of the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab), the U.S. institution that leads DESI's construction and operations.

"The mystery of dark matter and energy is a challenge to understanding how the universe behaves. State-of-the-art experiments like DESI are the best way forward to unravel these riddles," adds Ramon Miquel, the project's principal investigator at IFAE.

DESI is designed to automatically target pre-selected clusters of galaxies and collect their light to then scatter it into narrow bands of color. This will make it possible to determine with great precision the speed at which galaxies move away from us, to know their distance from Earth and to measure how much the universe expanded as this light traveled to us. Ideally, DESI can measure a new set of 5000 galaxies every 20 minutes.

5000 robotic fiber-optic "eyes":
DESI collaboration involves about 500 researchers from 75 institutions in 13 countries. In the last 18 months, the components of the instrument were sent from these institutions around the world to the Nicholas U. Mayall Telescope, located at the Kitt Peak National Observatory in Tucson (Arizona, USA), where they have been installed.

The instrument's primary mirror, 4 metres in diameter, and the set of corrective lenses, each about one metre in diameter, provide DESI with a large field of vision. The focal plane of the instrument is composed of 10 wedge-shaped petals, each containing 500 robotic positioners and a small camera that allows the telescope to be focused, aligned and pointed to optimally collect light from galaxies. The small positioning robots, which hold each of the optical fibers that collect the light, serve as the eyes of DESI.

DESI is able, in just 10 seconds, to automatically reposition all the optical fibers and focus on a new set of galaxies. Thanks to this speed, it will be able to map more than 20 times more cosmic objects than any previous instrument.

"DESI will not only contribute to substantially improving our understanding of dark energy, but it will also mean new knowledge about neutrinos, the most elusive particles known, since it is capable of measuring their influence on the evolution of the universe", qualifies Eusebio Sánchez, DESI's principal researcher at CIEMAT.

Among the last components installed is the set of spectrographs designed to divide the collected light into three separate colour bands and, thus, allow precise measurements of the distance of the observed galaxies. These spectrographs, which allow DESI's robotic

eyes to "see" even distant and faint galaxies, are designed to measure the redshift, which is a change in the color of cosmic objects to longer and redder wavelengths as they move away from us.

"The possibility of being able to simultaneously observe so many galaxies and measure their distance by obtaining their spectrum has required technological development to be able to produce such a high-precision instrument," adds Francisco Castander, as principal investigator of ICE-CSIC and IEEC.

Contribution of the Barcelona-Madrid group to the DESI project

The instrumental contribution to DESI of the Barcelona-Madrid Regional Participation Group, made up of researchers from IFAE, ICE-CSIC, IEEC, CIEMAT and IFT-UAM, has been the design, construction and installation of the complete Guiding, Focusing and Alignment system (GFA). This system is made up of 10 cameras, each of them installed in one of the focal plane petals of the instrument which, as its name indicates, are in charge of focusing, guiding and aligning the telescope so that the robotic positioners can collect the light from the galaxies under optimum conditions. This contribution has been led by IFAE, where the construction of the cameras has been carried out, with the collaboration of ICE, IEEC, CIEMAT and IFT. In addition, ICE and IEEC have led the production of the software to be able to point the whole instrument properly.

"The production of the self-guided cameras has required a great effort from all our team, where we have had to overcome many technological challenges in very tight times", points out Laia Cardiel-Sas, from IFAE and coordinator of the engineering team. "Our team is very satisfied with the performance of our cameras once installed on the instrument," adds IFAE engineer Otger Ballester.

"It is a huge satisfaction to be able to point a telescope that weighs 260 tons with a precision of microns, with our cameras and the software we have developed", concludes Santiago Serrano, ICE-CSIC and IEEC engineer. "After several years of working within the big family of the DESI collaboration, we are excited to see the first successful tests of the instrument and are looking forward to the scientific results that will come after starting operations," says Ricard Casas, also a researcher at ICE-CSIC and IEEC.

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Chapter 16

Outreach

16.1 Outreach talks

1. Mezcua, M., Agujeros negros supermasivos: los motores más potentes del Universo, , 22/01/2019

2. Trigo-Rodriguez, J. M., Asteroides i cometes un segle després del llegat de Comas i Solà, Centre Cívic Vil·la Urània, 23/01/2019

3. Busquet, G., La formació d'estrelles i sistemes planetaris, Universitat Autònoma de Barcelona, 16/02/2019

4. Sopuerta, C., Status de l'Astronomia d'Ones Gravitatòries, Institut de Secundària "Sagrat cor Sarrià", 19/02/2019

5. Sopuerta, C., Avenços en l'Astronomia d'Ones Gravitacionals, Campus UAB, 09/03/2019

6. Trigo-Rodriguez, J. M., Els meteorits i l'origen de la vida a la Terra, Aula Magna, Institut d'Estudis Il·lerdencs, (Lleida), 15/03/2019

7. Ribas, I., El descobriment del planeta Barnard b, Observatori de Sabadell, 24/04/2019

8. Elizalde, E., ¿Qué demonios es el Big Bang? ¿Me lo explicas? , Bacanal Café, Carrer de Sepúlveda, 164, Barcelona 08011, 20/05/2019

9. Elias-Rosa, N., ¿Supernova o impostor?, Observatori de Sabadell, 29/05/2019

10. Busquet, G., El naixement de les estrelles i la formació de sistemes planetaris, Aula d'extensió Universitària de Vilassar de Mar, Sala Roser Carrau, Vilassar de Mar, 22/10/2019

11. Elizalde, E., Els Orígens de la Cosmologia Moderna , Casa de Cultura, Sant Cugat del Vallès, 07/11/2019

12. Morales, J. C., Exoplanetes. Planetes més enllà del Sistema Solar, IES Eugeni d'Ors School, Vilafranca del Penedés, 19/12/2019

16.2 Other outreach activities

1. Casas, R., Visita al centre de la participant a l'esdeveniment "Ciencia en Acción" del CSIC, , 06/03/2019
2. Gálvez, J., Exposició 'COSMOS, Art Alienígena a Can Castells Centre d'Art (CCCA)', , 16/03/2019
3. Ribó, S., Anglada-Escudé, G., Orbital, , 11/11/2019
4. Casas, R., Què en sabem de la Lluna?, , 03/12/2019

16.3 In the media

1. Gaztañaga, E., A la recerca de l'energia fosca: sis anys per cartografiar la vuitena part del cel, 09/01/2019, `https://bit.ly/37ZT10Y`
2. Elias-Rosa, N., Una violenta explosión nunca vista antes desconcierta a los astrónomos, 11/01/2019, `https://bit.ly/2TeISIE`
3. Ribas, I., Un extraño planeta cerca del sistema solar, 25/01/2019, `https://bit.ly/2PppXK0l`
4. Trigo-Rodriguez, J. M., Un tipus especial de meteorit va portar l'aigua a la Terra fa 3.800 milions d'anys, 14/02/2019, `https://bit.ly/2SZ7MNe`
5. Trigo-Rodriguez, J. M., Nova prova que els meteorits van portar l'aigua a la Terra, 15/02/2019, `https://bit.ly/2SYmbtg`
6. Elizalde, E., Què és, i què no és, una teoria científica –Hubble mai no va creure que l'univers s'expandeix , 08/03/2019, :https://bit.ly/2YpK0xi
7. Ribó, S., El efecto 2000' llega a los dispositivos GPS, 27/03/2019, :https://bit.ly/2xuO18Al
8. Ribó, S., El GPS afronta el cambio en su estándar de fecha en abril y toca a los fabricantes evitar un nuevo 'efecto 2000', 27/03/2019, :https://bit.ly/2KR3pit
9. Ribó, S., Alguns GPS podrien deixar de funcionar el 6 d'abril, 28/03/2019, : https://www.elperiodico.cat/ca/extra/20190328/gps-efecto-2000-6-abril-2019-7379001
10. Rea, N., Entrevista a Nanda Rea en Ràdio 4, 29/03/2019, `https://bit.ly/2SXOx6N`
11. Ribó, S., Por qué tu navegador puede dejar de funcionar el 6 de abril, 29/03/2019, :https://bit.ly/3fd4mj1
12. Ribó, S., Life radio interview at Herrera en COPE de 12 a 13 horas. (01/04/2019) , 01/04/2019, :https://bit.ly/3di4fRN
13. Ribó, S., El 6 de abril tu GPS puede fallar, ¿conoces la razón?, 01/04/2019, : https://bit.ly/2KWaHBr

14. Ribó, S., Cuidado con tu GPS: a partir del 6 de abril puede fallar, 02/04/2019, : https://bit.ly/3aVeVnql
15. Rea, N., Les ejeccions d'un magnetar són un dels fenòmens més poderosos de l'Univers, 08/04/2019, `https://bit.ly/3c9dWCa`
16. Mezcua, M., Entrevista sobre agujeros negros para La Vanguardia, 10/04/2019, `https://bit.ly/32rGaUh`
17. Mezcua, M., Sopuerta, C., Entrevista sobre agujeros negros para El Periódico, 10/04/2019, `https://bit.ly/2PpqueY`
18. Trigo-Rodriguez, J. M., Els meteorits van portar aigua a la Terra, 22/04/2019, `https://bit.ly/2T3YS1j`
19. Cardellach, E., Atrapados (voluntariamente) en el hielo para estudiar cómo se derrite el Ártico, 23/09/2019.
20. Cardellach, E., Radio interview at La Linterna, Cope radio station , 25/09/2019.
21. Cardellach, E., Women Taking on Roles in Summer and Regional GRSS Activities, 26/09/2019, `https://bit.ly/2HW8l47`
22. Morales, J. C., Herrero, E., Un planeta gegant al voltant d'una estrella petita altera l'explicació sobre la formació de planetes, 26/09/2019, `https://bit.ly/2T16L7G`
23. Morales, J. C., Descubierto un exoplaneta gigante que desafía a los astrónomos, 27/09/2019, `https://bit.ly/3a8Ju9c`
24. Cardellach, E., Radio interview at 'Marca España' program in Radio Nacional, 01/10/2019.
25. Cardellach, E., Ciencia española en el Ártico: rompehielos, osos polares y temperaturas extremas, 28/10/2019, `https://bit.ly/2wJmXkZ`
26. Odintsov, S. D., Prof. S. D. Odintsov is interviewed by press-service of Baltic Federal university https://www.kantiana.ru/news/intervyu/professor-sergey-odintsov-v-lyuboy-moment-mozhet-proizoyti-kardinalnoe-izmenenie-nashikh-predstavlen/ , 10/12/2019, `https://bit.ly/3a6TUGs`
27. Mezcua, M., Conferència de Mar Mezcua a Sabadell sobre forats negres supermassius, 11/12/2019, `https://bit.ly/32Ai35W`

16.4 Our twitter account: @iSpaceSci

- Tweets: 137
- Followers: 663
- Retweets: 243
- Likes: 530

Chapter 17

Additional Social Activities and Strategy Retreat

- ICE Strategy Retreat January 9 - 10, 2019
- Christmas party, December 17, 2019